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DIVISION OF THE NERVES AND TENDONS OF THE HAND

WITH A DISCUSSION OF THE SURGICAL TREATMENT AND ITS RESULTS[1]

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IT is inevitable that men who are working along similar lines and who are interested in the same subject should often arrive independently at similar conclusions. In expressing such conclusions one may unwittingly assume that he is stating something that has not been expressed before and fail to realize that other workers in the same field have, perhaps long before, stressed the very facts and principles that have come to seem to him of fundamental importance. A few years ago in discussing the immediate treatment of injuries of the hand we emphasized the importance of a careful examination to determine the nature and extent of the injury before any operative treatment was attempted. Doubtless the same idea has been voiced by many men, but we only realized a few months ago that Torr W. Harmer (28) in 1922 had stressed it so definitely and described the method of examination so clearly that we seemed almost to be taking the words from his mouth.

Similar statements could doubtless be made concerning many of the details of technique which are suggested in the following pages. Incisions which avoid flexion creases, and which permit one to lay an intact flap of skin and subcutaneous tissue over sutured tendons and nerves have been advocated particularly by Bunnell[2] and by Harmer.

The importance of avoiding trauma and of handling tissues with the utmost gentleness is a primary article of faith with good surgeons everywhere. It was one of the principles that Halsted implanted so deeply in the minds of all his students.[3]

In connection with the surgical treatment of nerve and tendon injuries the importance of such technique has been frequently emphasized by both Bunnell and Harmer, by Steindler, by Stookey, by Naffziger, by Garlock, by Pollock and Davis, and by many others. Bunnell in 1921 presented a paper entitled, "An Essential in Reconstructive Surgery—Atraumatic Technique," devoted essentially to this one point; and in his later papers

[2] "It is important to have the skin incision remote from the tendon graft and tendon suture." Bunnell (10).

[3] "All of his publications had a very practical application, many of them pre-eminently so, for example, his introduction of the use of rubber gloves in surgery, his insistence upon the most meticulous care in the gentle handling of tissues, absolute asepsis and complete hemostasis." Finney.

"He learned how to treat the tissues as he made the wound that was later to heal. He treated them tenderly and watchfully, gently separating them and . . . tying with extremely fine black silk every minute bleeding vessel—so that in the course of his dissection everything was left clean and dry and above all not bruised or strangled. Equally careful was his attention to the bringing together of the tissues when the wound was to be closed—fascia exactly united to fascia, muscle to muscle, layer to layer, and finally the skin with carefully placed sutures." McCallum.

"He demonstrated that an operation lasting three and even four hours, if all the principles of surgery were utilized, did little harm to the patient. His painstaking devotion to hemostasis, to asepsis, to the delicate handling of tissue and to the artistic finish of his handicraft were of the greatest value to surgery. He introduced new hemostatic forceps with small jaws at the crushing points so that a minimum of tissue beyond the vessel was injured; he demonstrated the great decrease in the reaction in the wound when fine silk ligatures were used that included only the injured vessel; and his reapproximation of a wound attempted to bring together the tissues layer by layer as they belonged and without leaving dead spaces. His cases were a forcible demonstration of the fact that if the volume of blood is not diminished and the patient not otherwise traumatized, the duration of the anesthetic is of relatively little importance." Cutler.

[1] From the Department of Surgery, Northwestern University Medical School. Read in part before the Boston Orthopedic Club, Boston, Massachusetts, April 11, 1932.

constantly emphasized its importance. How well his results have justified his teaching is attested by Mayer's tribute, "His work is famous the world over. There is no one who can do what he can. . . . His results are accomplished by a technique that rivals that of the most proficient musician." His paper on "Reconstructive Surgery of the Hand" is the best article we have read on the subject. It could well serve as a textbook for every surgeon who is seriously trying to achieve good results in hand surgery.

The contributions of Leo Mayer, and Steindler, to the subject of tendon surgery are equally well known to every worker in this field. Mayer's original papers on the anatomy and physiology of tendons and his monograph on tendon transplantation, written in collaboration with Professor Biesalski, are outstanding contributions to the surgery of tendons.

In addition to the men mentioned are many others,—Auchincloss, Garlock, Mather, Bloch and Bonnet, Iselin,—whose names need only be mentioned to recall to the reader their interest in the surgery of tendons and the many helpful suggestions they have made toward its improvement.

We are equally indebted to another group of workers who have concerned themselves particularly with the physiological and pathological changes involved in nerve injuries, with methods of repairing such injuries, and with the clinical symptoms and signs following injury and operative treatment. The experimental studies of Howell and Huber, of Kirk and Lewis, and of Ranson on the processes of nerve degeneration and regeneration, the experimental work of Huber and his colleagues on nerve suture and nerve transplantation, and the careful clinical studies of Pollock on a large number of patients who had sustained various types of nerve injury are outstanding contributions in the American literature. Naffziger's paper on end-to-end suture of peripheral nerves is an admirable and comprehensive presentation of the technique of nerve suture. It is one of those contributions to which the student continually returns for helpful guidance. Stookey's well known volume on the surgical and mechanical treatment of peripheral nerves, Lewis' chapter on peripheral nerves in Lewis' *Practice of Surgery*, Foerster's encyclopedic monograph on the anatomy and physiology of the peripheral nerves, and on gunshot wounds of the peripheral nerves, and Pollock and Davis' monograph on peripheral nerve injuries are more recent contributions which cover in a thorough and exhaustive fashion the entire subject of peripheral nerve injury and repair. Babcock and Bower, Bunnell, Delagénière, Eisberg and Sonnenschein, Elsberg, Frazier, Joyce, Kennedy, Platt, Souttar and Twining and Stopford are only a few of many others who have made helpful contributions to the subject of peripheral nerve surgery.

Finally, we, personally, are very greatly indebted to Allen B. Kanavel for the helpful advice, the imagination, the enthusiasm, and the constant encouragement which he has given so generously to those who have had the good fortune to be associated with him. Many of the cases which are reported in the following pages have been his cases. The technique which we have described is patterned after his teaching, and if we have secured good results it is because we have tried faithfully to carry out the surgical principles which he has striven so hard to instill into us.

A primary consideration in the immediate treatment of an injury with tendon and nerve involvement, and one which is often neglected, is a careful examination of the patient to determine the degree and extent of injury.[4] Its importance may be illustrated by brief mention of a specific case. A man was seen two weeks after he had sustained a transverse cut over the volar surface of the right wrist. He had been operated upon less than two hours after the injury. His first words were, "I have had no feeling in the palm since the injury." In answer to our questions the surgeon wrote, "I know there was no nerve injury, for immediately after completion of the operation the patient was able to flex all his fingers."

Aside from the obvious fact that it is impossible to divide the flexor tendons by

[4] The necessity for careful examination before operation on the injured hand was mentioned above, but we believe the point is of such importance as to justify calling attention to it again.

transverse cut across the volar surface of the forearm just above the wrist without dividing the median nerve, and that it is difficult to divide the tendons without dividing the ulnar nerve (Fig. 1), is the often forgotten fact that even if both median and ulnar nerves are divided at the wrist a patient can flex his fingers if the flexor tendons are intact, since the long flexor muscles receive their innervation from the median and ulnar nerves high up in the forearm.[5]

Textbooks have made the picture of median and ulnar nerve injury unnecessarily difficult to visualize and remember, and these particular injuries are stressed because they are so common and so important. There are two pathognomonic signs of median nerve injury below the middle of the forearm—loss of sensation in the area of median nerve distribution (Fig. 2) and the inability to rotate the thumb to face the fingers.[6] Similarly there are two diagnostic signs of ulnar nerve injury below the middle of the forearm: loss of sensation in the area of ulnar nerve distribution (Figs. 2, 3), and loss of the ability to abduct the completely extended fingers from and adduct them to the midline of the hand. Such movements do not of course represent the entire motor function of the median and ulnar nerves, but they are unequivocal and diagnostic.

The function of the radial nerve (Fig. 3), of the digital nerves, of the long flexor tendons of thumb and fingers, and of the extensors of the thumb and fingers are too well known to require comment, and yet the failure to examine the hand and determine the extent of loss of function of nerves and tendons before carrying out any operative procedure often leads to unfortunate complications. "Forewarned is forearmed," and the surgeon who knows before operation that a certain nerve or tendon has been divided will not fail to find the injured structure and reunite it. How easy it would be to overlook certain nerve and tendon injuries if the pre-operative findings had not made one certain of their presence, the experienced surgeon knows full well.[7]

Fig. 1. Dissection of the volar surface of the wrist showing the superficial position of the median and ulnar nerves, and the similarity in size between the median nerve and the superficial flexor tendons (after Sobotta).

[5] So able a surgeon as John B. Murphy in discussing the loss of ability to flex the fingers in a patient who had sustained a deep glass cut across the volar surface of the wrist stated, "... there may be something wrong with the median nerve which supplies these muscles" and, a little later, "If the ... tendons were cut and then sutured, why is their function now suspended? It must be that the tendons either were cut and not sutured at all, or that they have become immobilized by union to the structures in the neighborhood. *A third possibility is that there is something wrong with the nerve supply. It is quite possible that the median nerve was divided and not reunited.*"

[6] Pollock (56) has shown that in cases of median nerve palsy the tip of the thumb can be apposed to the little finger by contraction of the flexor pollicis brevis and adductor pollicis. This movement, however, is not true rotation of the thumb, for the thumb is moved in a plane parallel to the palm.

[7] The emphasis that has been placed on the pre-operative examination of the injured hand is made with particular reference to the patient who is seen immediately after injury. It is unnecessary to add that the patient who comes for secondary operation should have as careful an examination and as accurate a pre-operative diagnosis as possible. We wish, however, to emphasize the importance of not delaying operation in late cases in which the exact diagnosis is in doubt until the most opportune time for operation, and particularly for nerve suture, has passed. It has invariably been our experience that in cases in which because of evidence of returning sensation there was doubt as to whether the nerve was completely divided, as to whether it had been properly united at the original operation, or as to whether spontaneous recovery was taking place the extent of nerve injury found at operation was considerably greater than anticipated. Frequently in such doubtful cases we have found nerve ends so widely separated that there was no possibility of union taking place without surgical intervention. The careful clinical studies of Pollock, particularly with reference to the development of overlap from adjacent nerves in an area whose normal sensory innervation has been disturbed, have been of very great assistance in helping us to understand these apparent anomalies, and to realize the importance of not placing too great reliance upon the evidence of returning sensation in an area whose nerve supply has once been cut off.

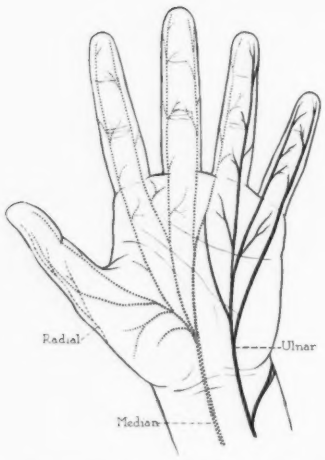


Fig. 2. The sensory nerve supply of the palm (after Spalteholtz).

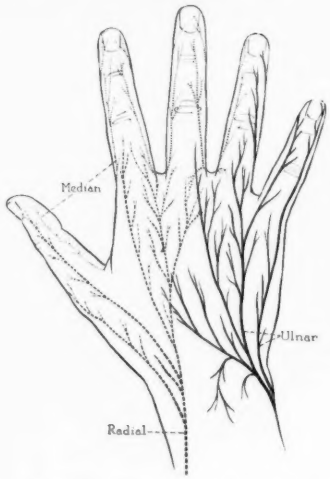


Fig. 3. The sensory nerve supply of the dorsum of the hand (after Spalteholtz).

A second and important consideration is that, to the patient who has sustained an injury with division of tendons and nerves, the greatest immediate danger lies not in the fact that function of the tendons and nerves has been lost, but that he has sustained an open wound through which virulent bacteria may gain access to the deeper tissues; and in the manipulation and dissection incident to repair of the injured structures these virulent bacteria may be disseminated widely and with disastrous results.[8] Such infection may jeopardize the patient's life. It cannot help but jeopardize the success of the operation, for no single factor is so important to success in the repair of tendon and nerve injuries as healing by primary union.

Although infection does not develop in every case in which immediate suture is performed (Figs. 4, 27, 28), it happens far too often. During the past year we have seen six patients, two of them physicians, in whom the immediate suture of divided tendons was followed by spreading infection, extensive sloughing, long continued suppuration, and eventually healing with marked loss of function. Such complications can be avoided by limiting very definitely the indications for immediate operation and by permitting cases in which these indications are not present to go on to complete healing before attempting surgical repair.

Under what conditions is one justified in carrying out immediate operation? In other words, under what conditions has one a right to expect wound healing without infection? A number of factors come into consideration: the conditions under which the injury has been sustained, the character and extent of the external wound, the exact location of the injury, the first aid treatment rendered, the time that has elapsed since the injury, and finally, the facilities available for its repair. If a tendon or nerve injury is the result of a clean cutting wound—from a glass, or broken bottle, or a porcelain water faucet, sustained indoors, and if the patient's hands are clean, there is a reasonable chance that the wound is not infected (Fig. 4). This possibility becomes less when the patient's hands are soiled, or covered with dirt and grease; when the injury is sustained out of doors—from flying glass, broken windshields, etc.; and when the external wound is a jagged lacerated wound of considerable extent (Fig. 5). The exact location of the injury is of importance. Tendons

[8] Garlock in 1926 emphasized the importance of delaying operation on injured tendons "when the wound is ragged and dirty, obviously grossly contaminated and the surrounding skin is covered with grime and dried blood." We agree entirely with Garlock's statement, but would limit much more strictly and definitely the indications for immediate operation.

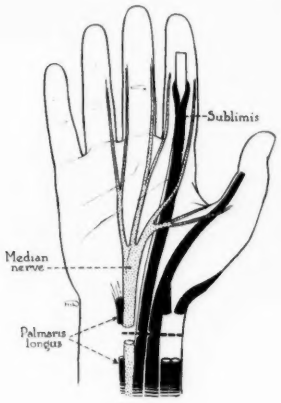


Fig. 4a.

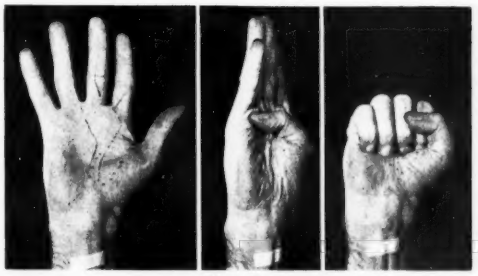


Fig. 4b.

Fig. 4c.

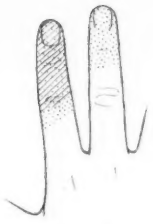


Fig. 4d.

Fig. 4. Division of median nerve, of flexor carpi radialis, abductor pollicis longus, palmaris longus, and partial division of flexor pollicis longus and flexor sublimis of index finger from a fall on a broken water bottle. Soap and water cleansing; primary nerve and tendon suture under ethylene anæsthesia 1½ hours after injury; primary union. a. Findings at operation. Solid black lines indicate injured tendons. b. Result 4½ months after operation. c, d. Sensory findings 4½ months after operation. Dotted area indicates loss of response to light touch; oblique lines loss of response to pin prick.

which are surrounded by definite sheaths are more vulnerable than those which are surrounded only by areolar tissue. Infection introduced into an open tendon sheath spreads readily from one end of the sheath to the other and very quickly involves its entire extent. If no sheath is present localization of the infection is favored and widespread diffusion of an infectious process is less likely to take place. The first aid treatment is of importance. If considerable bleeding occurs bystanders become alarmed and often contaminate the wound in their anxiety to control the hæmorrhage. The time element is important. If the injured hand is seen immediately, there is little opportunity for bacterial growth to take place, but if more than four hours have elapsed, we believe it is unwise to attempt primary operative repair. Finally, it seems unnecessary to say that the suture of divided tendons and nerves is a major operation, and one that should not be performed except in a well equipped operating room; yet one frequently sees cases in which such repair has been attempted in a doctor's office or a hospital emergency room with results that are far from ideal and difficult to counteract.

To state it in positive terms instead of negative terms, it is our belief that an immediate repair of divided tendons and nerves is justifiable if the wound is a clean cutting wound, made by sharp instruments, if the wounded hand is clean, if the cut is sustained indoors, if the first aid dressing has been sterile, if the patient is seen within a few hours of the time of injury, and if a well equipped operating room is available for surgical treatment.

If the median or ulnar nerve alone has been divided, without injury of tendons, one is justified in performing an immediate suture in some cases in which with extensive tendon injury immediate operation would not be justified, because divided nerves do not retract as divided tendons do and an extensive dissection to expose them is rarely necessary; and because the results of immediate nerve suture,

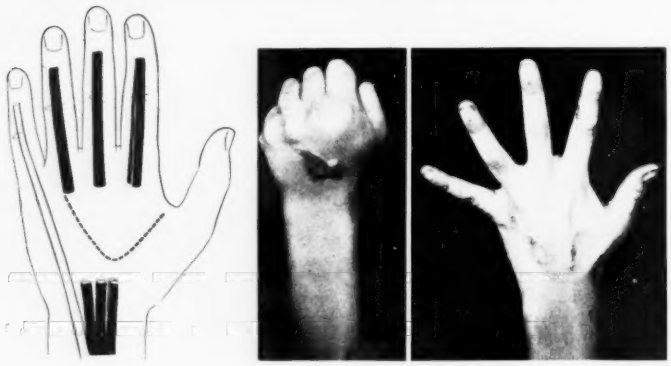


Fig. 5a. Fig. 5b.

Fig. 5. Division of extensor tendons of index, middle, and ring fingers by the edge of a broken mirror. Tendon suture under ether anæsthesia 4 hours later followed by wound infection and suppuration; healing complete in 7½ weeks. Excellent functional result in spite of postoperative infection. a. Findings at operation. Solid black lines indicate divided tendons. b. Result 1 year after operation.

particularly as regards the return of motor function, are so much better than the results of delayed suture that one is justified in taking a somewhat greater chance in order to secure an immediate end-to-end apposition.

If the conditions described above are not present, it is wiser to close the superficial wound loosely with a few interrupted sutures and permit healing to occur before attempting repair of the injured tendons and nerves (Figs. 6, 7). One should be particularly conservative about attempting immediate suture of tendons surrounded by a sheath. One occasionally sees cases in which the suture of tendons on the back of the hand has been followed by a slight localized infection without serious impairment of the operative result (Fig. 5), but we can recall but one case in which a low grade infection developed after suture of flexor tendons without impairment of the final result. In the majority of such cases which have come under our observation there has been extensive spreading of infection with eventual necrosis and sloughing of tendons, and in some cases sloughing of superficial tissues and ankylosis of joints as well—conditions which make it necessary to postpone any attempt at operative repair for long periods of time, and often make operative restoration almost impossible to accomplish.[9]

It is not necessary to present examples of the poor results of primary tendon and nerve suture. They are sufficiently common to have inspired considerable distrust in the medical profession concerning the wisdom of any operation upon tendons and nerves. On the other hand, it is hardly necessary to emphasize the fact that excellent results can be obtained in cases in which operation has been delayed until the original wound is soundly healed and free from every evidence of infection.[10] The duration of this delay depends upon the time required for wound healing, the character and amount of wound secretion, and the bacteriological findings. Wounds which heal by primary union can be safely reopened three weeks after the injury. If any wound discharge has been present it is wise to wait for three months after the wound is healed before carrying out secondary repair (Fig. 8). If the infection has been due to a hæmolytic streptococcus we believe that one must wait until the wound has been completely healed and free from discharge for twelve months

[9] Our emphasis upon the importance of delaying nerve and tendon suture unless one is certain that the wound is not infected is the result of our own early experiences with a few cases in which we performed primary nerve and tendon suture, and our observation of the results in a considerably larger number of cases in which immediate operation had been carried out elsewhere.

Our own results following immediate nerve and tendon suture are discussed in more detail under "Résumé of Cases of Divided Nerves and Tendons." (pp. 31–36.)

[10] "... to operate in the face of infection is to court disaster." Lyle. Although the writer was referring to the treatment of peripheral nerve injuries resulting from gunshot wounds the principle holds true no matter what the cause of the wound.

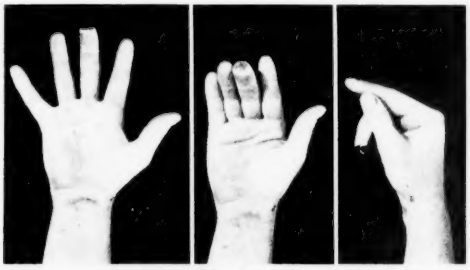


Fig. 6a.

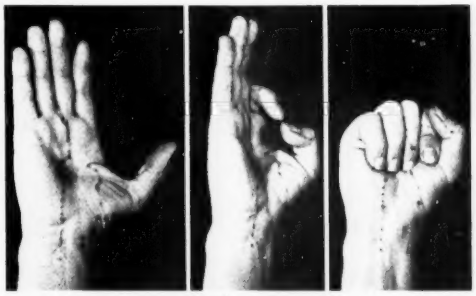


Fig. 6c.

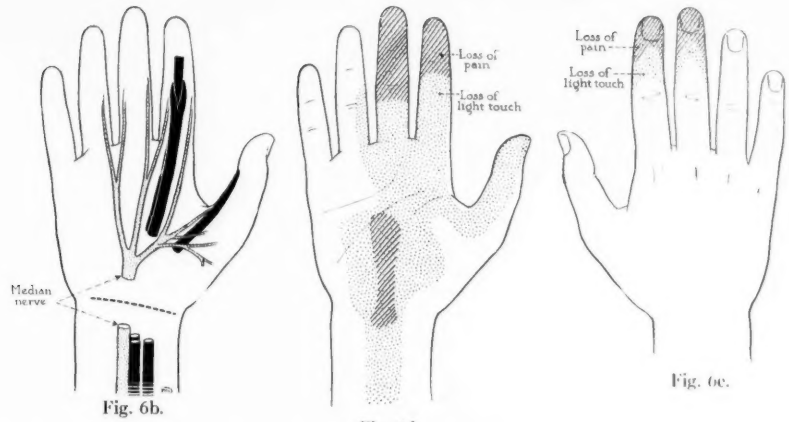


Fig. 6b.

Fig. 6d.

Fig. 6e.

Fig. 6. Division of median nerve, of flexor pollicis longus and both flexors of index finger; immediate skin suture elsewhere; primary union. Secondary nerve and tendon suture 26 days after injury. a. Before operation. b. Findings at operation. Solid black lines indicate divided tendons. c. Result and d, e, sensory findings 17½ months after operation. Dotted area indicates loss of response to light touch; oblique lines loss of response to pin prick. In spite of the objective loss of response to light touch the patient states that sensation is practically normal.

before he can carry out extensive secondary operations without danger of lighting up a latent infection.

Operative Technique

In the surgical treatment of tendon and nerve injuries several technical details are of great importance. First of these is care to ensure asepsis. In our judgment nothing in the way of surgical skill, accurate apposition of tendons and nerves, postoperative care, or postoperative physical therapy can compensate for failure to secure healing by primary union.[11] To render such healing as nearly certain as possible the hand and forearm are carefully prepared by thorough and prolonged cleansing with soap and water the afternoon before operation. A sterile dressing is then applied and left in place until the patient reaches the operating room. Just before operation the hand and forearm are painted with a solution of five per cent picric acid in fifty per cent alcohol.[12] An area on the ab-

[11] "Aseptic technique of a high standard is essential if good results are to be expected. It is no proof to the contrary if a case of nerve suture has become septic and yet a good result has followed: it will certainly be a very exceptional occurrence. Therefore the greatest care to prevent the entrance of organisms into the wound is a rule the importance of which cannot be overestimated. . . ." Kennedy.

[12] In the occasional case in which we have had the opportunity of operating upon patients with divided nerves and tendons within a few hours of the time of injury, it has for some years been our custom to prepare the field of operation in the operating room and, if a general anæsthetic is given, after the patient is anæsthetized.

Sterile dressings are laid over the wound itself and a wide area around it shaved and cleansed with soap and water. Next the wound itself is carefully cleansed with soap and water and with the help of small gauze

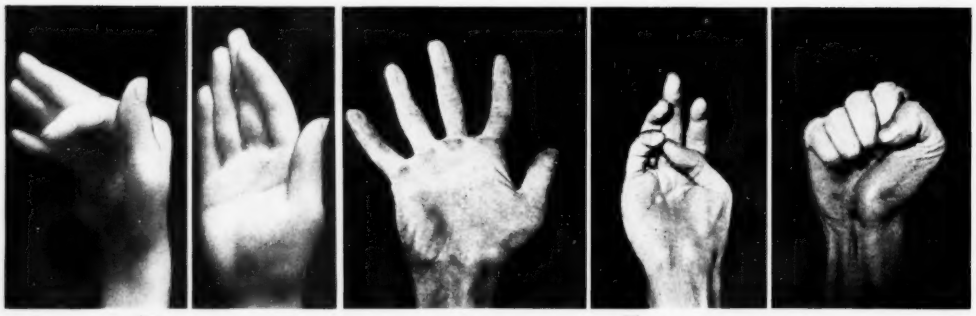


Fig. 7a.

Fig. 7c.

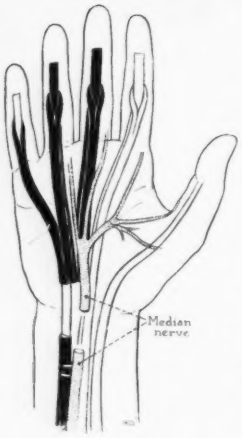


Fig. 7b.

Fig. 7. Division of median nerve, of both flexor tendons of middle and ring fingers, and of superficial flexor tendon of little finger. Immediate closure of skin wound; primary union. Secondary nerve and tendon suture 12 weeks later; primary union; secondary formation of a small sinus which remained unhealed until a single suture sloughed out 10 weeks after operation. a. Before operation. b. Findings at operation. Solid black lines indicate divided tendons. c. Result 2 years after operation.

dominal wall from which subcutaneous fat can be obtained is prepared in the same way, and if there is a likelihood that tendon grafts will be needed a foot is also prepared. In the operating room sterile linen is applied in such a way that hand, abdomen, and foot are accessible without shifting the sterile linen once it is in place.

Everyone who enters the operating room is masked; the nose is covered as well as the face, for we are convinced by our own clinical experience, and by Meleney's bacteriological studies that serious wound infection can result from failure to mask the nose as well as the mouth of everyone in the operating room.

sponges held in sterile forceps. The final step in cleansing is irrigation of the wound with a considerable quantity of warm sterile water.

We believe considerable harm is done to delicate and fragile tissue cells by irrigating such a wound with powerful chemical solutions, such as tincture of iodine, 95 per cent alcohol, etc., and that this harm outweighs any possible good that can be accomplished.

Although approximately one-third of our cases have been operated upon under local anæsthesia we prefer to use nitrous oxide, ethylene, or ether unless there is a contraindication for so doing. Scar tissue particularly is difficult to infiltrate and render anæsthetic by local infiltration. The injection itself adds a certain degree of traumatism. If tissues, particularly covering tissues, are already devitalized we cannot with safety use an anæsthetic solution containing adrenalin; and solutions without adrenalin do not render the part anæsthetic for a long enough time to permit one to carry out a complicated operation. Finally, the pressure of the blood pressure band may become unduly painful for the unanæsthetized patient after 30 or 40 minutes and make it necessary to release the constriction just at the moment when a bloodless field is essential.

Brachial plexus anæsthesia has certain theoretical advantages. Practically, we have found it difficult to secure constant and satisfactory anæsthesia with this method; and in attempting it we have always been concerned with the possibility of doing harm to important nerves or blood vessels by such a blind procedure.

Just before the operative incision is made the extremity is elevated for a few moments and the blood pressure cuff, applied beforehand, inflated to 220 or 230 millimeters. A bloodless field is indispensable for careful and accurate dissection and suture.

Finally, it should be unnecessary to repeat that gentleness in the handling of tissue, as has been so forcefully emphasized by Bunnell,

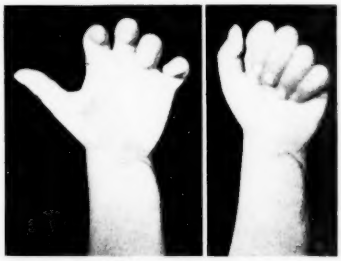


Fig. 8a.

Fig. 8b.

Fig. 8. Division of nerves and tendons of volar surface of forearm just above wrist from fall on a piece of glass; nerve and tendon suture elsewhere 2 hours later; primary union; persistent loss of sensation in palm and inability to extend fingers. At operation, 3 months later, median nerve and flexor tendons found fused into a single mass containing many strands of coarse silk; at the site of the divided ulnar nerve was a pecan sized abscess filled with gelatinous, purulent fluid. Contents of the abscess carefully wiped out; neurolysis of median nerve, tendolyses of flexor tendons, and end-to-end suture of ulnar nerve. Operative wound reddened and tender for some days, but healed by primary union. Cultures of abscess showed slowly growing colonies of staphylococcus albus. a. Before operation. b. Result 7 months after operation; the fingers can be flexed completely and extended almost to a straight line.

by Harmer, by Naffziger, by Pollock and Davis and many others, is of paramount importance in the treatment of nerve and tendon injuries. This gentleness must be directed not only to the handling of nerves and tendons, but to the superficial tissues as well. Necrosis of skin edges along the line of suture may result from forceful retraction and rough handling with tissue forceps and Allis forceps. Skin flaps often have diminished vitality because of the original injury and the subsequent scar tissue formation. Care and gentleness throughout the operation are important factors in helping to secure the primary wound healing which is so essential a factor in bringing about a successful result.

Although we have used special instruments for holding tendons, and have devised a tendon clamp to facilitate tendon suture we have finally come to depend upon very simple instruments: fine tissue forceps with teeth, so-called Adson forceps; very fine, straight arterial needles for tendon and nerve suture; No. D Corticelli white silk for the retention suture in the tendon and No. A Corticelli black silk for the coaptation suture in the tendon and for nerve suture; fine round needles with fine silk for suturing the deep fascia and subcutaneous tissue; and fine cutting needles with fine dermal suture or silk for the closure of the skin.

A sterile bipolar electrode to stimulate an injured nerve with the faradic current and enable one to determine the presence or absence of conducting fibers has been recommended by some surgeons as an essential feature of the operating room equipment. Although we have constantly kept such an apparatus available we have not found it of practical value. In the great majority of cases in which we were in doubt as to whether nerve division had been complete or whether spontaneous recovery was taking place we have found at operation unmistakable evidence of extensive injury, usually greater than we had anticipated. In a number of cases of median nerve injury, for example, in which the return of sensation in the area of median nerve distri-

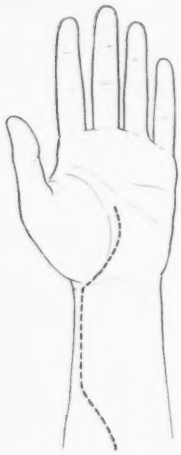


Fig. 9.

Fig. 9. Preferred incision for exposing divided nerves and tendons over the volar surface of the wrist.

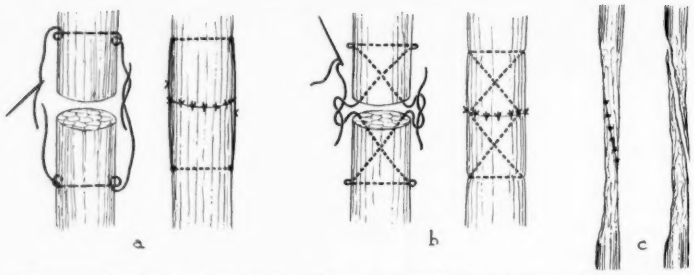


Fig. 10. Method of approximating the ends of divided tendons. a. The preferred method. b. An alternative method. c. Method of approximating the fragmented ends of scarred tendons when end-to-end union of freshened tendon ends is impossible because of extensive destruction of tissue.

bution suggested that recovery was taking place, we have found the nerve ends widely separated; and in other cases the proximal segment of the nerve united to a tendon and the distal segment lying free in the scar tissue floor of the wound. In no case in which the pre-operative examination left us in doubt as to whether recovery was taking place and in which at operation nerve ends were found united by a fairly normal appearing spindle of scar tissue were we able to secure a response from electrical stimulation of the nerve in question and, therefore, determine that resection of the neuroma and suture would not be necessary. In the majority of such doubtful cases resection of the scar tissue showed smooth connective tissue uniting the nerve ends and forming a complete block to the downgrowth of axons. Occasionally the excised section showed on its cut surface a few apparently intact nerve fibers, but in these cases also stimulation of the nerve above the site of injury had failed to produce contraction of the muscles supplied by the nerve in question.

INJURIES OF THE VOLAR SURFACE OF THE FOREARM AND WRIST[13] (Figures 4, 6, 7, 8, 13, 14, 16, 17, 18, 41, 42, 43)

The incision is planned, if possible, so that a flap of skin and subcutaneous tissue overlies the line of tendon and nerve suture (Fig. 9). It is very difficult to secure accurate and complete apposition of skin edges at and above the wrist when it is necessary to flex the wrist to permit nerves and tendons to come together without tension; but the difficulty is lessened if the incision crosses the flexion fold at the wrist near its radial or ulnar border.

After the incision is made the median nerve is dissected free, first above and then below the site of injury. It is always sought in sound tissue, and traced from above and below to the site of injury.[14] Just above the wrist, except for the palmaris longus, it is the most superficial structure underneath the deep fascia (Fig. 1). Higher in the forearm it lies at a deeper level, between the superficial and the deep flexor tendons. It can be distinguished by its slightly dull, grayish-white color in contrast to the glistening yellowish-white of the tendons, by its faint longitudinal striations, and by the tiny blood vessel that often lies upon its surface. It cannot be differentiated from the tendons among which it lies by its size. This probably accounts for the fact that in secondary operations one often finds the proximal segment of the divided median nerve sutured to the distal segment of one of the divided tendons. In locating the distal segment of the divided median nerve one should remember that it lies directly underneath the transverse carpal ligament. The ligament is thick and tough; it often closely resembles scar

[13] In the following discussion of the technique of operation in different locations and the operative incisions of choice we have in mind the cases in which operation is carried out after wound healing is complete, in other words, the secondary operations. If one has the opportunity of operating upon a clean case immediately after injury obviously he will adapt the operative incision to the open wound which is already present.

[14] "A long incision . . . identification of the distal and proximal portions of the nerve in their normal relations above and below the scar . . . is the first step." Naffziger.

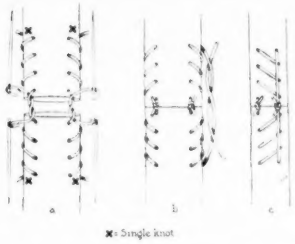


Fig. 11. Harmer's method of approximating the ends of divided tendons. (Boston M. & S. J., 1917, clxxvii, 808–810.)

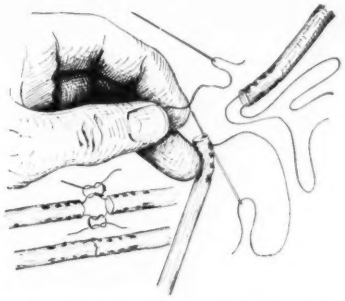


Fig. 12. Bunnell's method of approximating the ends of divided tendons. (J. Bone & Joint Surg., 1928, x, 10.)

tissue. Time can be saved by immediately dividing it in a longitudinal direction at the level of the wrist joint. The nerve can then be easily identified as it lies upon the flexor tendons just under the ligament.

After the median nerve is found the ulnar nerve is sought as it lies under cover of the flexor carpi ulnaris just medial to the ulnar artery and vein. In the forearm the accompanying blood vessels help to make easy its identification. The distal segment is more difficult to find, particularly if the point of division is close to the wrist. One should remember that as they pass from under cover of the flexor carpi ulnaris the nerve and its accompanying vessels lie just lateral to the pisiform bone, covered by a fascial expansion of the flexor carpi ulnaris (the volar carpal ligament), and that they pass into the hand superficial to the transverse carpal ligament in contrast to the median nerve which passes underneath the ligament. Not infrequently one finds the ulnar nerve divided just beyond the site of its division into deep and superficial branches. Both deep and superficial branches must be found and united to the proximal nerve trunk if one is to secure a satisfactory result.

With the nerves freed, covered with gauze or cotton saturated with salt solution, and held out of danger the tendons are next identified. Divided tendons always retract, and one must lengthen the incision if necessary in order to reach them. When the ends are exposed they can be grasped gently with fine tissue forceps and freed from the surrounding tissues by sharp dissection as far distally as one can see and reach with the knife. The superficial group is separated from the over-

Fig. 13. Partial division of ulnar nerve, complete division of median nerve and all of flexor tendons from fall on a glass bottle; immediate closure of wound elsewhere; primary union. Secondary operation 3 weeks after injury; suture *en masse* of proximal segments of deep flexors of four fingers to distal segments; suture of superficial flexor tendons in same way; end-to-end suture of flexor pollicis longus, of median nerve and repair of ulnar nerve. Primary union. Result 2½ months after operation. Patient is developing ability to flex fingers individually.

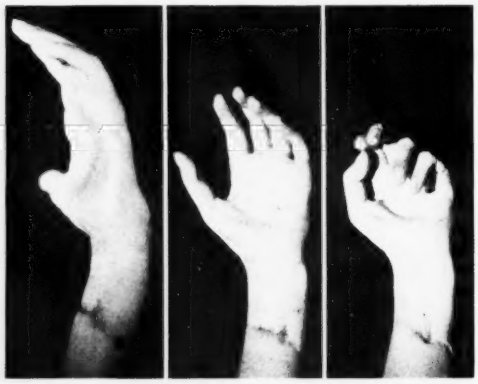


Fig. 14a.

Fig. 14b.

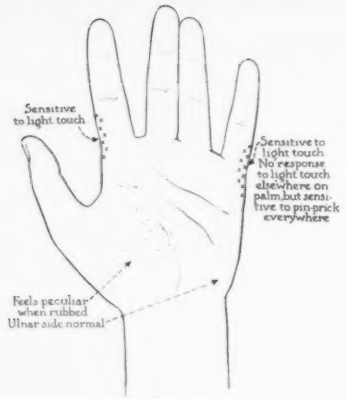

Sensitive to light touch
Sensitive to light touch. No response to light touch elsewhere on palm, but sensitive to pin-prick everywhere
Feels peculiar when rubbed. Ulnar side normal

Fig. 14c.

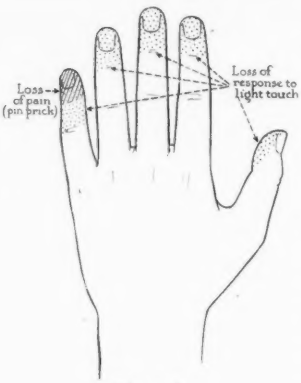


Fig. 14d.

Fig. 14. Printing press injury just below middle of left forearm with division of median and ulnar nerves and all flexor tendons except flexor pollicis longus. Immediate nerve and tendon suture elsewhere with persistent drainage for 2 months; no functional improvement. Secondary nerve and tendon suture 5½ months after injury; primary union. a. Condition before operation. b. Result 1 year, 8 months after operation; although proximal segments of deep tendons were sutured *en masse* to distal segments, and superficial tendons united in same way, patient has individual action of the index and middle fingers, but ring and little fingers are flexed and extended as one. c, d. Sensory findings 1 year, 8 months after operation.

moistened with salt solution[15] and the retracted tendons drawn proximalward into the wound. In favorable cases the adhesions which have formed in the digital sheaths give way and one can draw the fingers into complete flexion. In other cases the adhesions between the tendons and their sheaths have become so firm that no amount of tension can produce flexion at the interphalangeal joints. If one cannot produce flexion by direct tension upon the tendons one cannot expect the flexor muscles, which have been inactive for some time, to produce such flexion after suture has been performed, no matter how perfect the healing at the line of suture may be. In such cases in order to secure the desired result we have found it necessary to make an anterolateral incision in each finger and free the tendons from the surrounding fascia and from the deep group, and the deep group from the sides and floor of the carpal tunnel. When the surrounding adhesions have been divided, not torn, as completely as possible the ends of the tendons are grasped between the finger tips covered with gauze

[15] "Whether we are dealing with tendons or nerves we must handle them as little as possible. . . . I prefer to hold the structure with a piece of moist gauze in my fingers rather than to subject them to the uncertain compression of a smooth forceps, the bite of a toothed forceps, or the tearing of tiny hooks." Harmer (28).

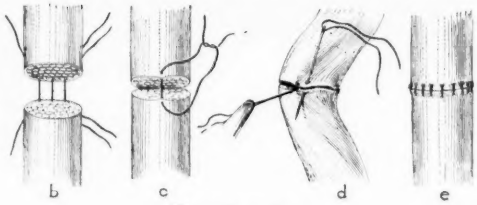


Fig. 15b, c, d, e.

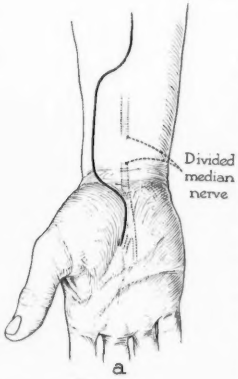


Fig. 15a.

Fig. 15. Technique of nerve suture. a, Incision of choice for exposing divided median nerve just above wrist. If necessary incision may be continued proximalward and distalward in vertical direction. b, First suture is inserted at exact midpoint of dorsal surface of nerve. A second and third supporting suture is inserted close to it before first is tied, to prevent first suture tearing through delicate epineurium as nerve ends are drawn together. c, After three sutures are tied a fourth is inserted at exact mid point of volar surface of nerve. d, Traction on suture helps to rotate nerve and facilitate introduction of next suture. e, Suture completed. f, Protection of line of suture with thin fat transplant.

dons from the surrounding tissues by sharp dissection. When this is done the firmest adhesions are usually found at the point of bifurcation of the sublimis, where the tendon of the profundus passes between the two slips of the dividing sublimis, and at the proximal end of the digital sheath, opposite the metacarpophalangeal joint. We have not been successful in attempting to free the flexor tendons from adhesions to the digital sheaths by "coring them out" with a modified cork borer.

If nerve destruction has taken place as a result of fibrosis or infection, nerves must be freed for a considerable distance proximalward so as to permit the ends to be brought together without tension. Some relaxation can be obtained by volar flexion of the wrist, but if this does not suffice the proximal segments of the nerves must be freed until complete relaxation is obtained.[16] By carefully

[16] "Free mobilization of the nerve requires, above all, long incisions. Small incisions and forcible stretching of the nerve produce unnecessary trauma and do not secure the greatest lengthening. The attachments of the nerve sheath to surrounding fascia will not be freed by pulling. It is often found that free mobility is prevented by small nerve branches to muscles. Careful exposure of these and gentle dissection of them for some distance up the nerve trunk will be necessary before the desired freedom of movement is obtained." Naffziger.

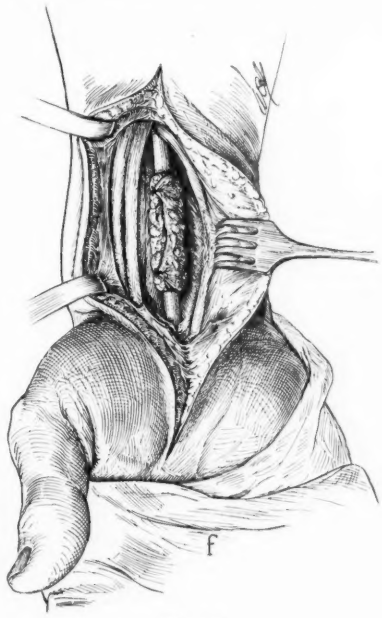


Fig. 15f.

separating the muscle bellies of the flexor sublimis from the underlying flexor profundus digitorum the median nerve can be freed almost to the elbow with little traumatism and without destruction of blood vessels. Flexion at the elbow gives still more relaxation. If both median and ulnar nerves are involved, and the loss of tissue is so great that the nerves must be freed to the elbow and the elbow flexed to relax the median nerve, it is necessary to isolate the ulnar nerve at and above the elbow, divide the fascial origin of the flexor group of muscles from the medial condyle and displace the ulnar nerve from the olecranon groove to the front of the elbow. As Naffziger has emphasized, one should be careful to preserve intact the branches of the nerve to the long flexors of the wrist and fingers. With the ulnar nerve displaced in front of the medial condyle flexion at the elbow relaxes the nerve instead of making it more taut.

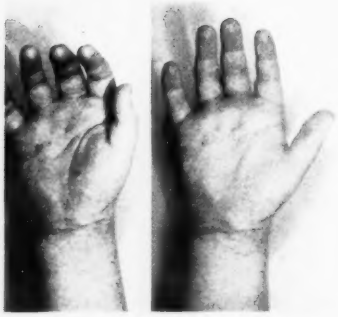


Fig. 16a.

Fig. 16c.

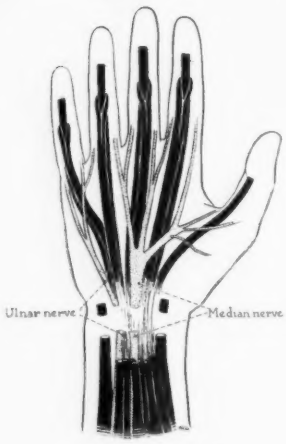


Fig. 16b.

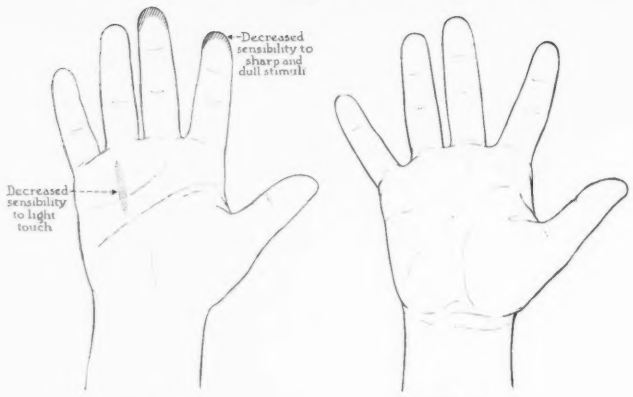


Fig. 16d.

Fig. 16e.

Fig. 16. Division of all flexor tendons, median, and ulnar nerves just above right wrist; immediate surgical repair elsewhere; healing by primary union, but without restoration of function. Secondary nerve and tendon suture 2 months after injury. Healing not complete until 2 small sutures were extruded 3 weeks after operation. a. Before operation. b. Operative findings. Solid black lines indicate divided tendons. c. Result 2 years after operation. d. Sensory return almost complete 2 years after operation. e. Tracing of hand showing degree of abduction of fingers possible 2 years after operation; the most definite evidence of return of motor function of the sutured ulnar nerve.

After the dissection is completed and the nerves and tendons are ready for suture the air is released from the blood pressure cuff, and any actively bleeding vessels are ligated. The arm is then elevated for a few moments, the cuff reinflated and the constriction maintained until the operation is completed and the bandage applied over the dressings. We have given up attempting to perform tendon and nerve suture in a bleeding field. The oozing from many tiny blood vessels is so great that the field of operation soon becomes discolored and the structures involved difficult to recognize. The amount of blood so lost is not inconsiderable; and the trauma to tendons and nerves from repeated sponging is surely not helpful.[17]

[17] Bunnell has said, "A tourniquet or blood pressure band should always be used to avoid the trauma of sponging" (9) and, "If we operate in a field rendered bloodless by the use of a blood pressure band as a tourniquet, we may avoid the unnecessary trauma of sponging, and can by clearly seeing the tissues dissect with exactness and a minimum of traumatism" (10). Taylor has said, "It is hardly necessary to mention that this work should be done in a bloodless field to secure clear recognition of the parts and to avoid the necessity of sponging, which if required should be done with moist absorbent cotton and not wiped with gauze."

Some surgeons on the other hand have advised against the use of a constrictor on the ground that "protracted constriction may not only affect the nerves, but the interference with circulation may so disturb the nutrition of the parts that repair processes may be retarded and resistance to infection reduced. Furthermore, prolonged use of the tourniquet may be followed by postoperative oozing." Harmer (28).

Tendons are sutured first, and, if possible, are sutured end-to-end. The type of suture we prefer to use is shown in Figure 10a. This type of suture has been advocated by Friedrich and by Max Lange of Munich. It is not essentially different from the technique advocated by Harmer (Fig. 11) and by Bunnell (Fig. 12). It fulfills the essentials which Mason and Shearon, in their experimental studies on tendon suture, have found to be of primary importance, viz., firm and accurate apposition of tendon ends without interposition of knots between the apposed ends, and

Fig. 17a.

Fig. 17b.

Fig. 17. Division of median and ulnar nerves and of all flexor tendons as result of glass cut in automobile accident. Immediate nerve and tendon suture elsewhere; primary union but with incomplete restoration of function. Secondary nerve and tendon suture 6 months after injury. a. Before operation. b. Result 17 months after operation.

without suture material threaded through the central portion—the core as it were—of the tendons. Sutures so placed, these workers have found, act as irritating foreign bodies at the very site where rapid and unimpeded proliferation of tendon and sheath tissue should go on if prompt and firm union is to take place.

If all the tendons are matted together at the site of division and the operation is a tedious and difficult one, we do not always separate the individual tendons of the superficial group and of the deep group to the four fingers from one another. In children, particularly, we have sometimes sutured the four superficial tendons above *en masse* to their respective tendons below, as though we were dealing with a single tendon, and have united the four deep tendons in the same way. In such cases we have still secured excellent results as far as individual action of the fingers is concerned (Figs. 13, 14). If healthy, clean cut tendon ends cannot be approximated, and the tendons can only be brought together by utilizing the strands of fibrous tissue which have bridged the gap between the ends of the divided tendons these strands are united by side-to-side union with fine silk sutures (Fig. 10c). If the latter method cannot be utilized, tendon grafts are taken from the foot to bridge the defect.

After the tendons are sutured the scarred nerve ends are amputated in successive thin

With a blood pressure apparatus used in the manner described, and with constriction maintained until the wound has been sutured and the pressure bandage applied, none of the complications suggested has occurred in any of our cases; on the contrary results have been better, particularly with regard to prompt healing and absence of postoperative swelling and discomfort, than when we attempted to operate without the use of a constrictor or with a constrictor applied during a part of the operation.

Again, we repeat, we are referring to the secondary operations and not to the cases operated upon immediately after injury. In the latter cases we have usually not found a constrictor necessary.

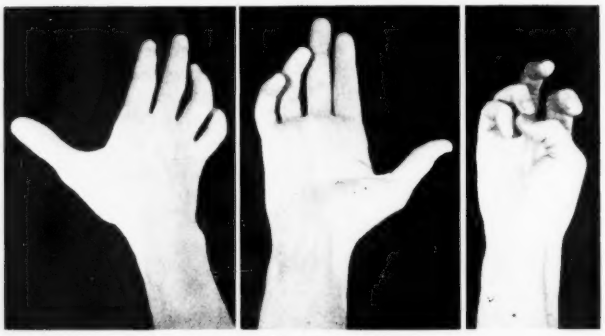


Fig. 18a.

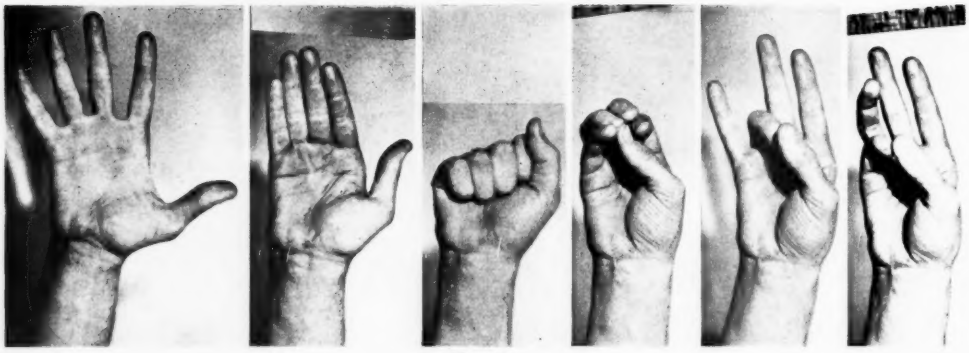


Fig. 18b.

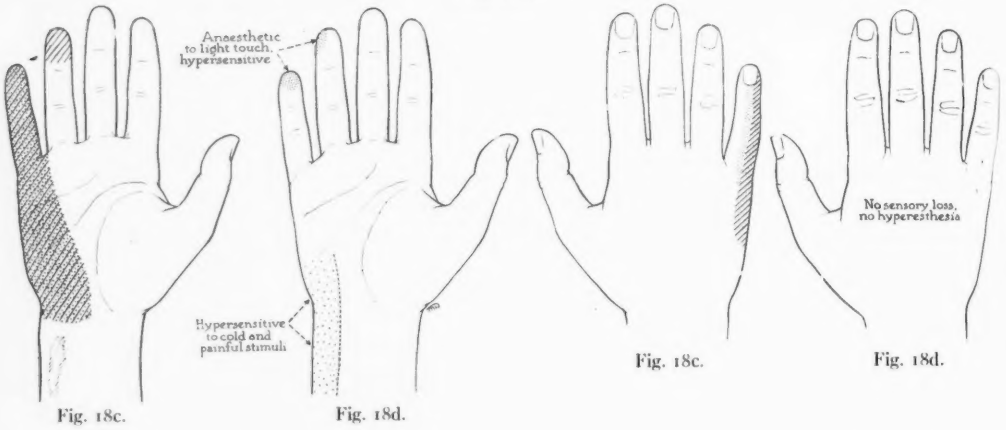

Anaesthetic to light touch, hypersensitive
Hypersensitive to cold and painful stimuli
No sensory loss, no hyperesthesia

Fig. 18c. Fig. 18d.

Fig. 18c. Fig. 18d.

Fig. 18. Division of ulnar nerve and several flexor tendons as result of fall through glass door. Immediate tendon suture elsewhere; primary union. Suture of ununited ulnar nerve one year after injury; suture line protected with fat transplant from abdominal wall; primary union. a. Before operation. b. Result 13 months after operation, with ability to abduct and adduct fingers c. Sensory findings before operation. Dotted area indicate extent of loss of response to light touch; oblique lines los of response to pin prick. d. Sensory findings 13 month after operation. Restoration of function rapid in view o time elapsing between division and suture of nerve.

slices until healthy nerve ends are reached. The nerves are united end-to-end by very fine silk sutures which include only the epineurium (Fig. 15).[18]

In the light of our present knowledge, and as the result of our experience with three cases in which extensive gaps in nerves were bridged with fascial tubes, we have not felt justified in attempting any other methods of repairing divided nerves.

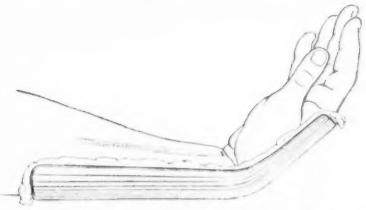


Fig. 19. Aluminum splint for maintaining volar flexion at the wrist after suture of the ulnar nerve.

The value of plastic procedures or of nerve transplants to bridge a gap between divided nerve ends is still a controversial question. Two aspects of the subject we believe have not received the attention they deserve. The experimental work of Huber, Lewis, Corbett, Stookey, and Roberg on the use of nerve transplants was carried out on healthy animals; a segment of normal nerve was excised and immediately replaced by some type of graft. In only a few cases on record has a similar procedure been carried out in man. In the great majority of cases in which nerve transplants have been performed in man, a considerable interval of time has elapsed between the injury and operation, with resulting atrophy of all the tissues innervated by the divided nerve and degeneration of its distal segment. Not infrequently there has been severe wound infection and extensive scar tissue formation as well. Under such conditions the problem is obviously a different one from the transplantation of a healthy living nerve graft, or of a preserved graft, into normal tissue to replace a newly made defect in a normal nerve. In the second place, as Pollock has so clearly shown, careful discrimination must be used in interpreting the clinical symptoms present after operations on nerves. One must be particularly careful not to confuse the residual sensibility due to overlap of adjacent nerves with return of sensation due to nerve regeneration, and not to confuse supplementary movements and re-education of normally innervated muscles with return of motor function in muscles supplied by the divided nerve.

With reference to the value of nerve transplants or of plastic operations on nerves Lewis stated (41), "I believe that I have two cases in which there are decided evidences of return of function after the use of the auto-cable transplant." Nine years later he stated (42), "Accurate end-to-end suture gives the best results and should be performed in all cases when possible," and, "A number of different procedures have been employed to bridge a defect in a peripheral nerve so long that an end-to-end suture cannot be made. . . . Edinger introduced the formalinized calves' arteries. Tubes of Cargile membrane, fascial tubes, and decalcified bone tubules have all been used. Occasionally a success has been reported

[18] "Many technical details have been emphasized with regard to the exact method of nerve suture. The essentials are delicacy of handling and the avoidance of trauma, accurate suturing without tension, with the use of a minimum amount of foreign material to favor the production of fibrous tissue, and the proper protection of the parts afterward." Naffziger.

"Catgut and especially the tension catgut sutures of Gosset, so generally used, we have carefully avoided after observing the absorptive reaction and liquefaction produced in nerves by the catgut used abroad, and the absence of reaction from fine silk." Babcock and Bower.

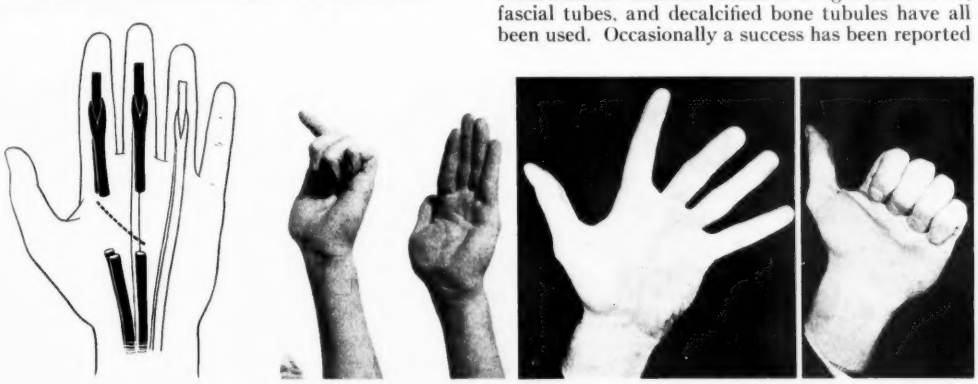


Fig. 20b. Fig. 20a. Fig. 20c.

Fig. 20. Division of flexors of index and superficial flexor of middle finger as result of porcelain faucet injury. Immediate tendon suture elsewhere; primary union, without functional improvement. Secondary tendon suture 6 weeks later; primary union. a. Before operation. b. Findings at operation. Solid black lines indicate divided tendons. c. Result 6 years after operation with complete restoration of flexion at both interphalangeal joints.

Fig. 21a.

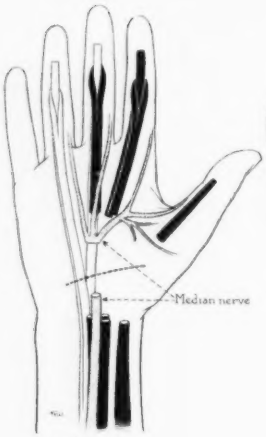


Fig. 21b.

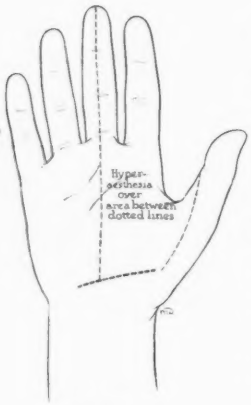


Fig. 21d.

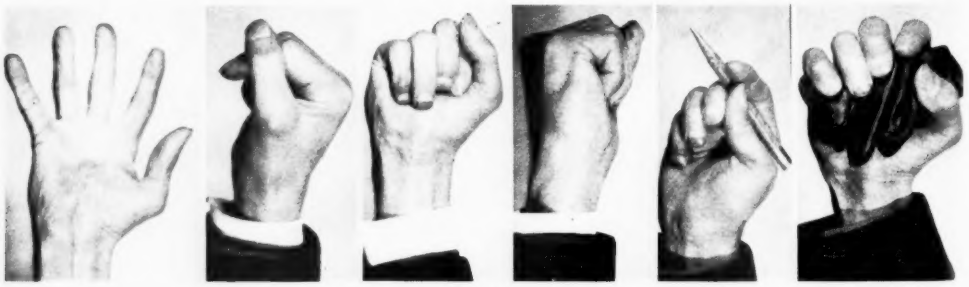


Fig. 21c.

Fig. 21. Division of median nerve, flexor pollicis longus, both flexors of index and superficial flexor of middle finger as result of deep cutting wound of palm from a broken porcelain faucet. Immediate operation elsewhere; healing by primary union, but without recovery of function. Secondary nerve and tendon suture 2½ months aft injury. Primary union. a. Before operation. b. Findin at secondary operation. Solid black lines indicate divid tendons. c. Result 13 months after operation. d. Senso findings 2½ years after operation.

after the employment of some such procedure. In such cases, however, the possibility of double nerve supply of the muscle or muscles and of supplementary movements should be considered. These procedures cannot be depended upon and should be discarded.

"The transplantation of segments of nerves has been attempted from time to time; auto-, homo-, and hetero-grafts being used. Eden, for example, removed the tibial nerve in the case of an amputation and transplanted it into a defect in the musculospiral measuring 20 centimeters. After two years there was no improvement. Transplantation of segments of nerves has been repeatedly attempted with almost uniformly bad results. Occasionally a success has been reported. In some of the cases which have been operated upon the second time some neurofibrillæ have been found in the transplant but they have not progressed far.

"Cable transplants have been tried without much success. Segments of nerves preserved in alcohol, as suggested by Nageotte, are not successful.

"Tubulization and grafts experimentally employed have given a great deal of information concerning the methods of repair in peripheral nerv but the results thus obtained cannot be appli directly to man."

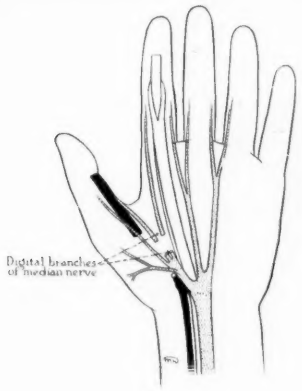


Fig. 22a.

Fig. 22b.

Fig. 22. Division of flexor pollicis longus and digital nerves to cleft between thumb and index as a result of a porcelain faucet injury. Immediate closure of skin, followed by hæmatoma formation and slight wound discharge for 10 days. Secondary nerve and tendon suture 5 weeks after injury. Primary union. a. Findings at operation. Solid black lines indicate divided tendon. b. Result 4 months after operation.

Delagénière in discussing the surgical repair of peripheral nerves in the light of the results obtained in 375 wounded men stated that in 94 cases "incorrect sutures" were performed. In 8 of these the gap between the nerve ends was bridged with strands of catgut; in 8, the nerve was partially divided and reversed; in 3, the two living ends of the nerve were anastomosed with an adjacent nerve. All of these operations resulted in failure. In 65 cases in which the resection of one or both ends of the nerve was insufficient there were 22 failures. With reference to "distant suture" (bridging a gap with strands of catgut), tubular suture (bridging a gap with a tube of autoplastic or heteroplastic substance) and neuroplastic methods he says, "No good results have followed these procedures." With reference to autotransplants he says, "I have used the autoplastic graft with some results. I took portions of the musculocutaneous nerve of the leg. I have had a complete recovery with the radial nerve and two very fair results with the ulnar. How can we explain these results in the case of the ulnar which is a mixed nerve? Whatever the explanation may be it has been proved true that by means of grafting fragments of the musculocutaneous nerve of the leg as long as 13 centimeters, the peripheral nerve has recovered its function."

Bunnell reported very striking results following nerve transplantation—6 successful results in 6 cases.

Stookey has summed up the situation admirably: "When all procedures to obtain end-to-end approximation have failed, and a nerve defect remains to be bridged, there is only one method which has shown promise, histologically and experimentally, namely, cable transplants of autogenous nerve segments. The experimental evidence presented by such painstaking investigators as Huber (1895–1918), Cajal (1918), and others has been so overwhelmingly in support of this method that it cannot readily be discarded. Clinically, however, the percentage of failures is very great. This pronounced difference between the clinical and the experimental evidence must be considered.

"Clinically, transplantation has been used as a last resort when all other procedures have been abandoned. Under such circumstances the defects

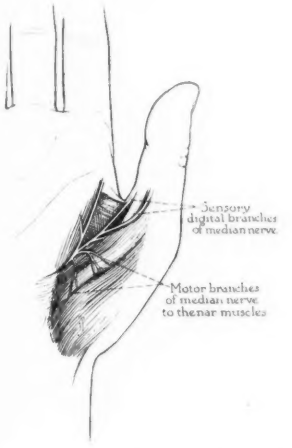


Fig. 23. Dissection showing the position of the motor branches of the median nerve to the thenar muscles.

Fig. 24a.

Fig. 24c.

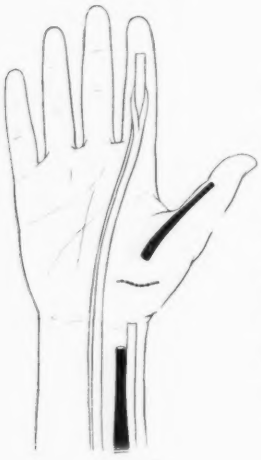


Fig. 24b.

Fig. 24. Division of flexor pollicis longus as result of glass cut in a 4 year old child; immediate operation elsewhere with unsuccessful search for proximal segment of divided tendon; healing without infection. Secondary operation 7 weeks later, with end-to-end suture of divided tendon. a. Before operation. b. Findings at operation. Solid black lines indicate divided tendon. c. Result 2½ years after operation.

to be bridged are unusually long and in many instances the nerve grafts are placed in a dense scar bed. Often interstitial sclerosis in both the central and distal segments of the nerve is present. Under such circumstances, successful regeneration by any method, even end-to-end suture, an infinitely simpler method, requiring less skill and fastidiousness, would be seriously jeopardized.

"Many failures are to be attributed to faulty technique rather than to the method itself. . . .

"In view of the above facts, there is little wonder that nerve grafts are generally considered of no clinical value. Scattered through the literature, however, are quite a few reports of successful regeneration following the use of transplants, among them those by Gosset, Delagénière, André-Thomas, and Villandre, Forrester-Brown, Joyce, Frazier, and Stookey. These reports show that clinically, nerve defects *can* be bridged by nerve transplants, thus supporting the foundations laid and the conclusions drawn from experimental work. In view of this and of the sound principles involved, it would seem expedient not to condemn this method as yet."

Care is used not to rotate either segment of the nerve in approximating the divided ends.

Stoffel and his followers emphasized the importance of such care in order that corresponding funiculi of the divided nerve segments might be brought into exact apposition, and that sensory and motor fibers above might be brought into contact with sensory and motor fibers below. The anatomical studies of Heinmann, Borchardt and Wjasmenski, Langley and Hashimoto, and others, however, showed that "a definite funicular arrangement is found only within a short distance of the point at which nerve branches are to be given off" (Stookey) and that because of the many internal plexuses present in the peripheral nerves "the motor paths lie more or less constant only a short distance from the

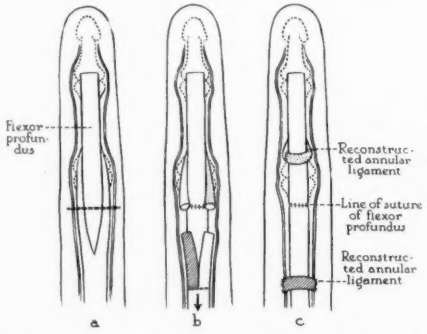


Fig. 25. Method of utilizing the slips of insertion of the flexor sublimis to form an annular ligament to hold the sutured flexor profundus in apposition with the volar surface of the finger, and of holding the flexor profundus in apposition with the volar surface of the proximal phalanx.

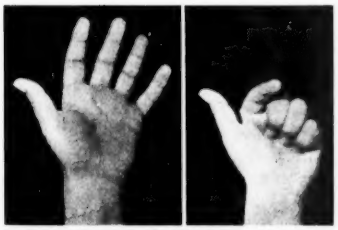


Fig. 26a.

Fig. 26b.

Fig. 26c.

Fig. 26. Division of the flexor tendons of left index and of overlying digital nerves from a porcelain faucet injury; immediate operation elsewhere with primary union but without restoration of power of flexion. Secondary nerve and tendon suture 3 months after injury; both superficial and deep tendons united end-to-end; remains of lumbrical muscle laid between the two tendons to prevent adherence to one another. a. Before operation. b. Findings at secondary operation. Solid black lines indicate divided tendons. c. Result 2 months after operation.

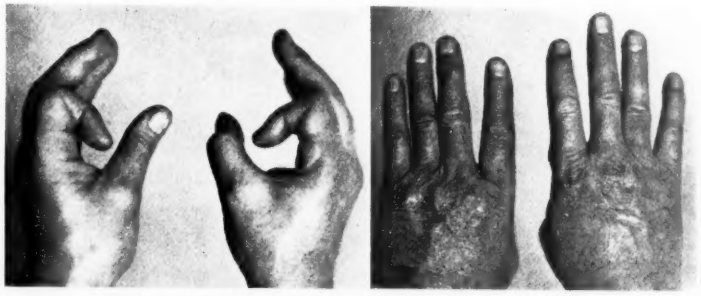


Fig. 27. Division of flexor profundus tendon of right index finger opposite the distal interphalangeal joint; primary suture under gas and ether anæsthesia 24 hours after injury, primary union. Result 2 years after operation.

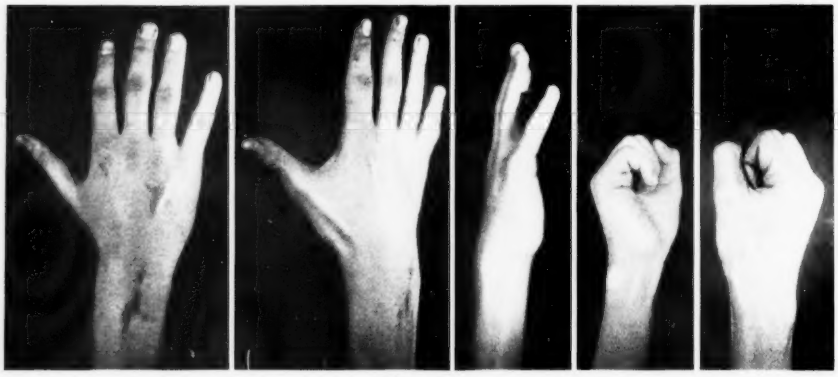


Fig. 28b.

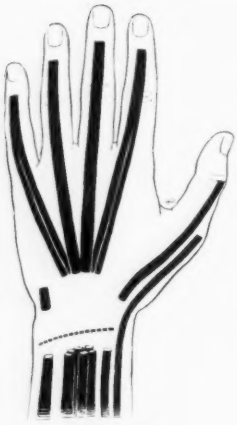


Fig. 28a.

Fig. 28. Division of extensor pollicis longus, extensor indicis proprius, extensor communis digitorum, and extensor carpi ulnaris as result of fall through glass window. Tendon suture under local anæsthesia 2 hours later; primary union. a. Findings at operation. Solid black lines indicate divided tendons. b. Result 7 months after operation.

point at which they leave the nerve stem" (Borchardt and Wjasmenski). Huber as a result of experimental studies stated, "I am confident that it is not necessary in practical work to give undue stress to Stoffel's studies on the specific funicular structure of nerves. Any one who has worked experimentally with regeneration of nerves realizes that from 10 to 50 new neuraxes may bud toward the periphery from a single central neuraxis, and 15 or 20 new neuraxes are often found centrally in a single old neurilemma sheath. No matter how carefully primary suture is made, there is a great tangle of these new nerve fibers as they pass through the connective tissue of the wound, and expecially is that the case with secondary sutures. A large number of fibers pass from the stump along the transplant in the connective tissue surrounding the transplant. I am sure sensory nerve fiber branches reach the motor nerves; and that central motor nerves reach the distal sensory nerves and are maintained for a time. They make no distal connection and in time degenerate."

The nerve suture can sometimes be facilitated by inserting a temporary suture through the nerve sheath on the under surface of each segment about an inch from the point of division. Traction on the two sutures helps to draw the nerve ends together and relieve tension while the permanent sutures are inserted.

If the first suture is placed at the very center of the posterior or deep surface of the nerve, and a second and third suture inserted at either side of the first suture before the first suture is tied accurate apposition is facilitated. If there is some tension on the nerve ends it is difficult to secure accurate apposition over the deep or posterior surface if the suture is begun on the anterior or superficial surface.

If fat from the subcutaneous tissues at the site of operation can be obtained to separate the deep from the superficial tendons and to protect the lines of nerve suture this is utilized. If not, fat is taken from the abdominal wall and very thin layers of fat laid between deep tendons and carpal tunnel, between deep and superficial tendons and about lines of nerve suture.[19]

[19] Conflicting ideas have been expressed concerning the use of fat transplants about sutured tendons and nerves. The recommendations of the elder Rehn in this respect are well known. Huber reported an experiment in which subcutaneous fat was wrapped around a nerve transplant; in 238 days "the fat sheath was entirely replaced by dense connective tissue. . . . This argues strongly against fat sheaths in peripheral nerve repair." This conclusion, however, was made on the basis of a single experiment.

Later Huber stated, "There is one more point I should like to refer to in connection with our experimental work, namely, the importance of having dry, clean wounds, before the wound is closed. There would appear to be a correlation between a field not quite dry and an increase of connective tissue about the nerve operated upon." It is our belief that the latter point is the essential one as far as the formation of connective tissue in a clean wound is concerned.

Lewis has said, "After the suture is completed the nerve should be placed when possible in a new muscle bed. The dissection should

Finally the deep fascia and subcutaneous tissue are approximated as accurately as possible with fine silk sutures, the skin edges carefully approximated and a massive gauze dressing bandaged snugly in place. Only when the bandage is in place is the air released from the constricting cuff. Since using this method of maintaining a bloodless field we have never found it necessary to open a wound to let out accumulations of blood, and have invariably found our wounds soft and free from tension when the primary dressing was changed.

Usually it is necessary to apply a splint to maintain flexion at the wrist for a time and so eliminate tension on sutured tendons and nerves (Fig. 19).[20] If flexion at the elbow is necessary to give relaxation of the sutured nerves the splint is designed so as to include the elbow as well.

Active and passive movements of the fingers which do not cause tension upon the line of skin suture are begun at the first change of dressings, twenty-four hours after operation. As soon as the superficial wound is healed sufficiently so that more extensive movements can be carried out without danger of separating wound edges, active movement and physical therapy are begun and continued daily. The length of time during which flexion at the wrist is maintained depends upon the degree of flexion that has been necessary to permit approximation of tendons, and particularly of nerves, without undue tension. The flexion splint is gradually straightened during the second and third week and removed in all cases by the end of the third week.

Fig. 29. Preferred incision for exposing divided extensor tendons over the dorsal surface of the wrist.

INJURIES OF THE PALM
(Figures 20, 21, 22, 24, 26, 40)

The line of incision depends to a certain extent upon the position and extent of the original injury. Four general principles should be kept in mind: An adequate incision reduces operative trauma; the attempt to free important structures from surrounding adhesions by subcutaneous dissection is frequently unsuccessful and often leads to futile and unnecessary prolongation of the operation. Second, the incision should follow if possible the normal flexion creases of the palm.[21] Third, the incision can often with advantage be planned so that the old scar is excised. Finally, the blood supply of skin flaps must be given due consideration, and any modification of that blood supply which may have resulted from the original injury. As with injuries at the wrist it is very desirable to have a flap of skin and subcutaneous tissue to lay over the line of nerve and tendon suture so that normal tissue may cover the site of repair of nerves and tendons.

After the skin incision is made and the site of injury exposed one must first isolate the

made when possible along intermuscular septa so that the muscle fibers of these muscles which may later be needed to form the new bed for the nerve are not cut. It is not necessary to use any of the numerous methods to cover the suture line which have been advocated."

We believe, however, that there is a logical basis for the use of a pedunculated or free transplant of fat about a sutured tendon or nerve, for loose areolar tissue and fat are normally present about these structures, with the exception of those portions of the tendons which are surrounded by definite synovial sheaths. At the wrist or in the hand it is impossible to place the sutured nerves or tendons in a new muscle bed. There is no muscle available. Moreover, it has not often been possible in our experience with nerve suture above the wrist to place the sutured nerve in a bed of muscle without dividing muscle fibers obliquely, and bringing about some bleeding at the site of division. All of our experience confirms Huber's last statement, quoted above, that there is a definite relation between the dryness of the operative field at the close of operation and the amount of subsequent scar tissue formation.

[20] "Physiologists have shown that the union of a sutured nerve occurs soon, but is not firm until after four weeks. After this period a sutured nerve cannot be torn off by the normal motions of limbs, even if it was sutured in flexion, and there is no danger in putting the limb through gradual progressive movements of extension." Delagénière.

[21] "Many fingers are permanently crippled by the median longitudinal incision. . . . If the median longitudinal incision of the finger, whether on the dorsal or the palmar surface, through the matrix or in the pulp, whether for infection or repair, be eliminated entirely from the surgeon's activities, many fingers will be saved from being permanently damaged. Even in the palm the longitudinal incision leads to contraction. It is far better to make transverse incisions in the palm in the line of the creases or L-shaped ones than longitudinal." Bunnell (10).

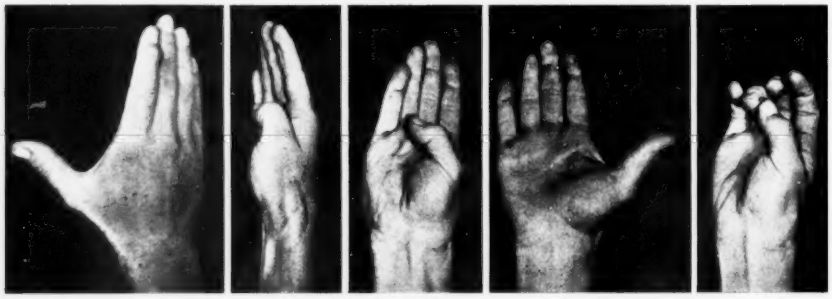


Fig. 30b.

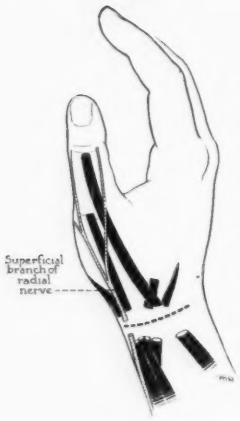


Fig. 30. Division of extensors of radius, both extensors and long abductor of thumb, and of superficial branch of radial nerve as result of razor cut. Immediate closure of wound with clips. Tendon suture elsewhere 6 days later; primary union without functional result. Secondary nerve and tendon suture 3½ months after injury, primary union. a. Findings at operation. Solid black lines indicate divided tendons. b. Result 21 months after operation.

Fig. 30a.

digital nerves. These small nerves control the motor function of the lumbrical and thenar muscles, sensation in the palm and fingers, and trophic function of the innervated muscles and in the area of sensory distribution. They lie just underneath the palmar aponeurosis and slightly superficial to the tendons. They are usually bound tightly in the fibrous tissue which holds aponeuroses, nerves, blood vessels, tendons, and sometimes overlying skin in a mass of scar tissue. Unless they are sought and recognized at the very beginning of the operation they may be hopelessly damaged or even remain unrecognized. In these operations there is no royal road. As with injuries at the wrist one must find the nerves above and below the site of injury and trace them from normal tissue into scar tissue. Of particular importance is it to recognize and guard from injury the motor branch of the median nerve to the thenar muscles, to free it from scar tissue and suture it if divided. The paralysis of the thenar muscles which results from its division, and the resulting loss of ability to rotate the thumb so that it faces the fingers are important elements in the loss of function resulting from median nerve injury. The nerve usually appears as depicted in Figure 23 and leaves the sensory digital branch to the ulnar side of the thumb at a level close to the middle of the first metacarpal bone.

Of equal importance is it that the digital blood vessels which accompany the digital nerves should be guarded from injury. Failure to do so may result in necrosis and gangrene of one or more fingers. We have not hesitated to divide the superficial palmar arch if necessary to secure adequate exposure or facilitate removal of scar tissue, but whenever possible it has been left intact.

After nerves and blood vessels are freed and protected from injury the tendons must be found. Frequently the divided ends will have retracted a considerable distance from the site of injury and may be difficult to find. Because it lies in a separate sheath and so does not become adherent to the adjacent tendons, the proximal segment of the divided flexor pollicis longus, particularly, is likely to retract into the forearm and it may be necessary to follow it to a level above the wrist, or to make a separate incision above the wrist in order to locate it (Fig. 24). Often in searching for the proximal segment of a divided flexor tendon it is possible to distinguish the thin fibrous tissue remains of the empty sheath or of the areolar tissue which surrounded the tendon in the

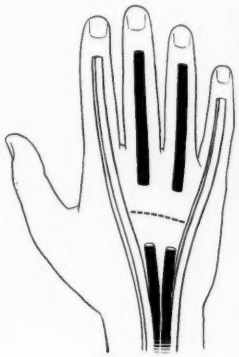


Fig. 31a.
Solid black lines indicate divided tendons.

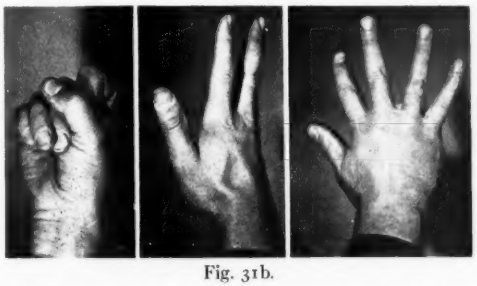


Fig. 31b.

Fig. 31. Division of extensor tendons of middle and ring fingers by fireman's axe; immediate wound closure elsewhere without tendon suture. Secondary tendon suture 7 weeks after injury, with transplantation of fat under sutured tendons; primary union. a. Findings at operation. b. Result 4 years after operation.

palm. By putting tension upon this tissue the end of the tendon can be drawn downward into the wound. The tendon itself is recognized through its covering of areolar tissue by the yellowish tinge at the edge of the cut tendon, which is now more or less completely fused with the surrounding connective tissue. This fusion definitely limits its movement, but if the adherent areolar tissue is completely excised by sharp dissection free movement of the tendon is again made possible.

In locating and freeing the distal segments of the divided tendons care must be taken to preserve if possible the fibrous tendon sheath or enough of it to act as an annular ligament opposite each phalanx. If this is impossible new annular ligaments must be constructed after the tendon repair is completed.

The problem of uniting tendons which have become widely separated is sometimes a difficult one. If both superficial and deep tendons cannot be approximated without undue tension, the distal stump of the superficial tendon can be excised and a part of the proximal segment utilized as a free graft to bridge the gap between the retracted ends of the deep tendon. In such cases one of the slips of insertion of the sublimis may be left attached at its insertion, laid transversely across the profundus and the free end sutured on the opposite side to the fibrous tissue remains of the flexor sheath, so as to form a new annular ligament to hold the deep tendon in place (Fig. 25).[22] A thin segment of tendon may also be laid across the deep tendon at the middle of the proximal phalanx and sutured on each side to the remains of the fibrous sheath so as to form a new annular ligament at the level of the web (Fig. 25c); or, as Bunnell has suggested, a strip of tendon or fascia may be passed around the proximal phalanx underneath the extensor tendon so as to encircle the bone and the flexor tendon. With the ends sutured rather snugly a firm annular ligament is formed to hold the tendon in place over the volar surface of the bone.

If it is possible to bring proximal and distal segments of both superficial and deep tendons to a finger together in the palm without undue tension, the question arises as to the wisdom of having two lines of suture at the same level and in close approximation, and whether the two sutured tendons will not adhere to one another and so fail to move freely. We have sometimes met this problem by laying the lumbrical muscle between the two tendons at the line of suture and holding it in place by one or two fine sutures. Figure 26 shows the result obtained in such a case in which both flexors of the index finger and the digital nerves to adjacent sides of the thumb and index had been divided just below the level of the outstretched thumb.

After the tendon repair is completed the

[22] "One of the great difficulties (in tendon transplantation) is to provide phalangeal annular ligaments where they have been destroyed so as to prevent tendon prolapse. If the flexor sublimis tendon has its dividing slips along the side available, it is possible to use these. If not, it may be necessary to transplant fascia." Auchincloss (3).

Fig. 32a.

Fig. 32b.

Fig. 32. Division of extensor pollicis longus and digital nerve to ulnar side of thumb from pocket knife injury; suture of skin elsewhere 12 hours later; healing slow; complete in 3 months. Secondary tendon and nerve suture 8½ months after injury; primary union. a. Findings at operation. Solid black lines indicate divided tendon. b. Result 1 year after operation.

divided nerves must be sutured. In the hand this is often more difficult than at the wrist, for not uncommonly it is necessary to suture two or three small branches below to the larger nerve trunk above. Bunnell has suggested that in such a case the small distal segments may with advantage be gathered into a single bundle by a circular suture before end-to-end suture is performed. The necessity of removing sufficient scar tissue to expose healthy nerve fibrils results in a gap of varying extent between proximal and distal segments. This gap can usually be bridged by freeing the proximal segment above and gently drawing it downward and by flexing the fingers at the metacarpophalangeal joints. Freedom from tension on the line of nerve suture, and particularly upon the small and delicate distal segments (the digital nerves) is essential for success.

The use of a thin flap of fat to separate sutured tendons and nerves from overlying skin and to protect the line of nerve suture is helpful in securing a successful result. If subcutaneous fat can be secured at the site of operation it is always utilized, otherwise fat is secured from the abdominal wall.

INJURIES OF THE VOLAR SURFACE OF THE FINGERS

Although tendon division may occur at any point along the volar surface of the proximal and middle phalanges the most common site of injury of the tendons within the fingers is at their base, approximately at the level of the web. At this level there are three tendons within the flexor sheath—the two halves of the flexor sublimis, separating from one another and passing toward their insertion on the base of the middle phalanx, and the single tendon of the flexor profundus, passing underneath the dividing sublimis toward its insertion on the base of the distal phalanx.

In operating upon such cases in earlier years we made the mistake of attempting to suture all the divided structures, and to bring about a complete anatomical restoration. This was always difficult, because the distal slips of the flexor sublimis were invariably short, and because they were thin and flat, or slightly crescentic in cross section. Furthermore the suture of three distinct structures at the same level tended to bring together a considerable mass of sutured tissue in a comparatively small space, with the result that the formation of adhesions between deep and superficial tendons was favored and the gliding movement of the tendons impeded.

Bunnell's successful results following the transplantation of a single tendon into a finger from which both flexor tendons had been removed showed that a single tendon attached to the distal phalanx is adequate for maintaining the function of flexion. In cases in which the flexor tendons were divided between the level of the metacarpophalangeal joint

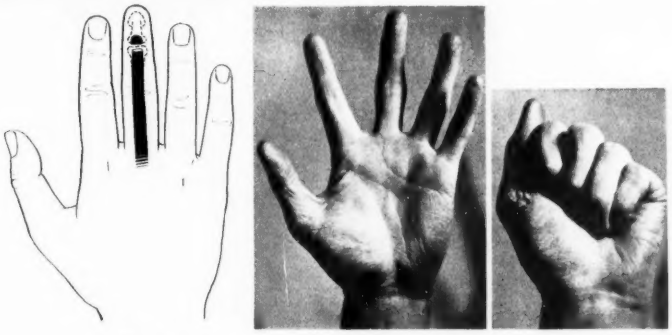


Fig. 33a. Fig. 33b.

Fig. 33. Subcutaneous rupture of extensor tendon of middle finger. a. Findings at operation. b. Result 1 year after operation.

and the base of the middle phalanx we therefore began to depend upon the suture of the profundus alone and to utilize the slips of insertion of the flexor sublimis in the construction of a new annular ligament to hold the profundus in place opposite the middle phalanx. This plan of procedure gave more satisfactory results than the former method, but the results of suture of the tendons within the fingers are still far from perfect, and are less satisfactory than those of tendon suture in any other location.[23]

As with injuries in the palm the operative incision is made in such a way as to avoid cutting across the normal folds and creases of the skin, usually along the most accessible lateral surface. The digital nerves and vessels are sought first of all and are carefully protected from injury during the course of operation. The tendon sheath is opened widely enough to expose the tendon ends and free them completely from the adhesions which fix them, and to permit careful and accurate suture. Occasionally it is possible to preserve enough of the sheath opposite the proximal and opposite the middle phalanx to act as an annular ligament and hold the sutured tendon in apposition to the phalanges during flexion. Usually, in our experience this is not possible. Too often, as a result of the infection and fibrous tissue formation which followed the primary injury, even though the infection has been minimal, the tendon and the sheath, in which it glides freely under normal conditions, are converted for some little distance from the site of injury into a solid cord of fibrous tissue. The portion of the sheath left empty by retraction of the ends of the divided tendon collapses. Although at times it may be possible to open the sheath and free the tendon within it, rarely is there sufficient space within the sheath for the sutured tendon to glide freely. Under normal conditions the tendon is held snugly by its sheath. If the tendon is thickened as a result of injury and the insertion of even fine suture material, there is simply not sufficient room for the tendon to move freely.[24] Moreover, as a result of the injury the lining walls of the sheath are no longer smooth shining surfaces, but are dull and fibrosed. Such conditions favor reformation of adhesions and militate against free movement. We have usually therefore found it necessary to excise the remains of the tendon sheath at the site of injury so as to provide adequate space for the thickened tendon, and to depend upon early

[23] There are two reasons for this fact: the rapidity with which adhesions form in the finger about the sutured tendon and the relatively poor blood supply of tendons surrounded by synovial sheaths. Mason and Shearon have shown in their experimental work on tendon suture that the blood supply of the tendon is an important factor in healing, and that sutured tendons surrounded by loose and vascular areolar tissue heal more rapidly and firmly than tendons enclosed in a synovial sheath, and which depend for their blood supply chiefly upon small blood vessels such as are present in the vincula tendinum of the flexor tendons in the fingers.

[24] A striking illustration of this fact is the condition known as snapping finger. Following a comparatively slight injury, such as a sudden pull applied to a flexed finger or sudden hyperextension of an extended finger, the patient complains of localized pain, and subsequently develops a "snap" i.e., an interference with complete flexion or complete extension which occurs at a definite and constant point in the arc of movement. At operation there is often found a spindle shaped enlargement of the tendon just distal to the proximal termination of the flexor sheath in the palm; and this enlargement, though slight, is sufficient to interfere with the free gliding movement of the tendon in its sheath.

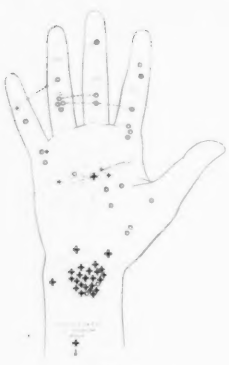


Fig. 34.

Fig. 34. Nerve and tendon injuries of the volar surface of the right hand and forearm (the marker indicates the site of injury; + indicates division of both nerves and tendons; O of tendons alone.)

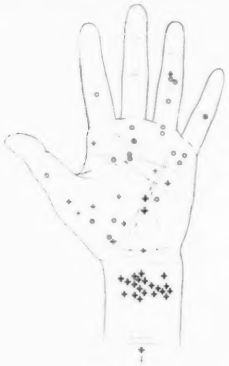


Fig. 35.

Fig. 35. Nerve and tendon injuries of the volar surface of the left hand and forearm (the marker indicates the site of injury; + indicates division of both nerves and tendons; O of tendons alone.)

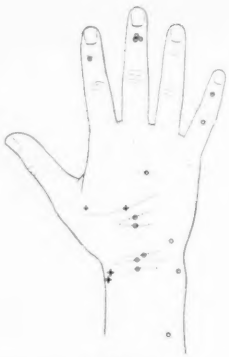


Fig. 36.

Fig. 36. Nerve and tendon injuries of the dorsal surface of the right hand and forearm (the marker indicates the site of injury; + indicates division of both nerves and tendons; O of tendons alone).

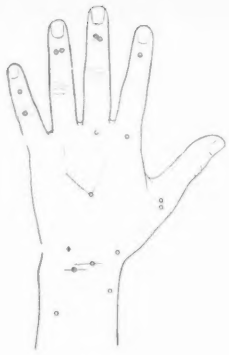


Fig. 37.

Fig. 37. Nerve and tendon injuries of the dorsal surface of the left hand and forearm (+ indicates division of both nerves and tendons; O of tendons alone).

movement to prevent the formation of adhesions and fixation of the tendon to the surrounding soft tissues.

The utilization of the slips of insertion of the sublimis tendon as a substitute for the fibrous flexor sheath opposite the middle phalanx has been mentioned. A simple plan consists in the utilization of a single slip, which is left attached at its normal insertion and laid transversely across the profundus; its free end is sutured with fine black silk to the fibrous expansion of the extensor tendon at the side of the finger. A short strip of tendon may be laid in the same way across the profundus opposite the middle of the proximal phalanx and sutured to the fibrous tissue on either side to form a retaining ligament opposite the point of greatest stress (Fig. 25).

If the deep tendon alone has been divided, beyond the point of insertion of the flexor sublimis (Fig. 29), suture may be rendered difficult because the distal stump is short and almost inaccessible for accurate suture from a lateral incision. It is in such cases particularly that an incision in the shape of an inverted L (T), with its transverse limb at the distal flexion crease of the finger, may be helpful. In such cases one must also be certain that the remains of the fibrous tendon sheath does not form a barrier to the full movement of the tendon as it is drawn upward by contraction of the flexor muscle; or that the new annular ligament, if one is provided, does not form a similar obstruction.

Finally after tendon repair is completed, the digital nerves, if they have been divided, are united by end-to-end suture.

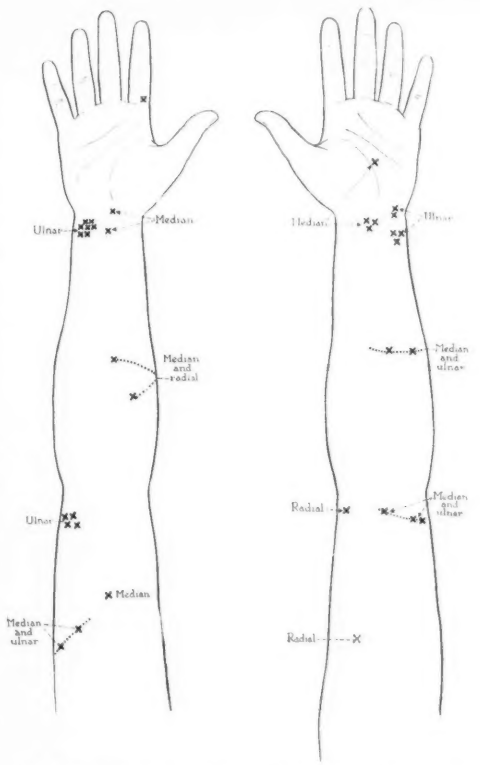
INJURIES OF THE DORSUM OF THE HAND
(Figures 5, 28, 30, 31, 32, 33)

While injuries of the dorsum of the hand with division of the tendons and nerves may occur at any point the majority of them are included in one of four groups: (1) injuries on the dorsum of the wrist with division of the extensor tendons of the four fingers; (2) injuries on the radiodorsal surface of the wrist with division of the long abductor of the thumb and the extensors of the thumb and wrist; (3) injuries on the dorsum of the metacarpus; and (4) subcutaneous rupture of the extensor tendon opposite the distal interphalangeal joint. With tendon injuries included in the first three groups there may be division of one or more of the sensory branches of the radial or ulnar nerves.

Injuries on the dorsum of the wrist frequently result in a division of the extensor

digitorum communis with or without concomitant division of the extensor indicis proprius, extensor digiti quinti proprius, and extensor carpi ulnaris (Fig. 28). The fact that the first of these passes underneath the dorsal carpal ligament through the same compartment as the extensor digitorum communis makes it almost inevitable that it should be injured if the common extensor is divided. Common characteristics of these injuries are the marked retraction of both segments of the divided tendons and the fact that usually both proximal and distal segments are firmly matted together by scar tissue for some distance from the point of division. Since a muscle relieved of its normal tension immediately contracts to the resting stage the proximal segments of the divided tendons retract upward into the forearm. Because the flexor muscles are more powerful than the extensors and since the normal position of the relaxed hand is with the fingers in semiflexion the distal segments of the divided tendons are drawn distalward, with the result that the gap between the divided ends is even greater than it is ordinarily after tendon division. Too often the advantage of splinting the injured hand in the position of dorsal flexion immediately after injury has been overlooked, and an additional degree of avoidable separation has taken place.

In the operative exposure of such injuries a crescentic or a flap incision (Fig. 29) with its center opposite the site of injury has several advantages. It permits one to lay a flap of fairly normal skin and subcutaneous tissue over the sutured tendons. It may make it possible to avoid entirely cutting across the healed scar, and so make more certain primary healing of the operative wound. It facilitates closure of the incision when the wrist is held in dorsal flexion. If, on the other hand, one makes a vertical incision along the midline of the forearm and directly across the scar, dorsal flexion of the wrist forces the edges of the incision apart and renders closure of the wound extremely difficult. Too often such an incision fails to heal at the site of greatest tension, where the operative incision crosses the scar of the original injury, the wound begins to gape, and tissue necrosis and wound infection take place, with the result that healing is delayed and the ultimate result definitely impaired.



Figs. 38 and 39. Left, nerve injuries of right upper extremity; right, nerve injuries of left upper extremity. In these cases, either a nerve only was injured, or the coincident tendon injury had been repaired elsewhere at the primary operation.

In making the operative incision and raising the flap it is necessary to remember that the sensory nerves lie just underneath the subcutaneous tissue, superficial to the deep fascia overlying the tendons. As in operations elsewhere on the hand the nerves must be recognized and isolated at the outset of the operation or they will be irreparably injured.

Before the divided tendons can be united it is necessary to free them from the surrounding scar tissue to such an extent that a pull applied directly to the proximal segments draws them well down into the field of operation, and a pull applied to the distal segments

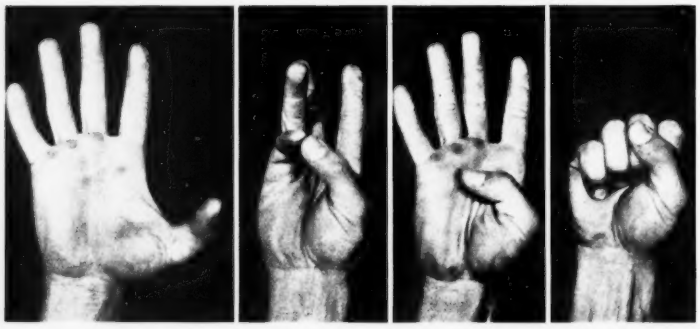


Fig. 40. Division of flexor pollicis longus. Tendon suture 48 hours after operation followed by infection of tendon sheath and radial bursa. Result 4 years after operation.

produces complete extension of the affected fingers. It is not necessary and usually not wise to separate the tendons from one another and unite them individually; they would simply become adherent to one another again. The operation, moreover, would be prolonged and rendered more difficult, for the individual tendons are so narrow and slender that their approximation is much more difficult than that of a larger tendinous mass.

Injuries on the radiodorsal aspect of the wrist may cause a division of the abductor pollicis longus and extensor brevis, of the extensor pollicis longus alone, of all three tendons, or of the three tendons and the underlying extensors of the radius (Fig. 30). If one remembers that the first two tendons pass under the dorsal carpal ligament through the compartment farthest to the lateral side and form the most marked prominence on the lateral aspect of the wrist, that the extensors of the radius pass through the next compartment and at a slightly deeper level and that the extensor pollicis longus passes through a third compartment still more medial and more superficial than the second, it is easy to understand why certain tendons are likely to be divided in certain types of injury either alone or characteristically in association with other tendons. If one keeps in mind this association he is not likely, for example, to fail to find and unite the divided extensor brevis if the abductor longus has been divided; or to look for injury of the extensors of the radius if the three more superficial tendons have been divided.

Injuries on the dorsum of the metacarpus may involve one or more of the extensor tendons of the fingers (Figs. 5, 31). Because the individual tendons are united laterally by the oblique bands which pass between them and held to a slight extent by the areolar tissue which surrounds them retraction of the divided tendons is not so marked as after injuries on the dorsum of the wrist, for example, and suture of divided tendons on the dorsum of the metacarpus is relatively easy. If after operation the fingers are supported on a cock-up splint, so that there is no tension upon the line of suture for a period of from ten to fifteen days, one should secure a perfect result in practically every instance.

Subcutaneous rupture of the extensor tendon opposite the distal interphalangeal joint (Fig. 33) was discussed by Mason in a paper published in this journal in March, 1930, and the operative treatment carefully described. As Mason pointed out the site of rupture is usually just opposite the joint. In cases seen immediately after injury the tendon may appear intact when first exposed, because the thin sheath of areolar tissue which surrounds the tendon is stretched but not divided. When this sheath is dissected free the ruptured tendon is exposed. In cases seen some time after injury the ends of the tendon are united in a lengthened position by a bridge of connective tissue which has formed within the sheath of areolar tissue. We have secured the best results by excising this thickened connective tissue and bringing the clean cut tendon end into accurate apposition. If one simply divide

Fig. 41a.

Fig. 41b.

Fig. 41. Division in automobile accident of median nerve and all flexor tendons over volar surface of left wrist except deep flexor of little finger. Primary suture of nerve and tendons followed by severe spreading infection and extensive destruction of superficial and deep tissues.

Secondary suture of median nerve and flexor pollicis longus 16 months after injury. a. Result after primary suture and subsequent infection (just before secondary operation). b. Result 3 years after secondary operation. c. Sensory findings 3 years after secondary operation.

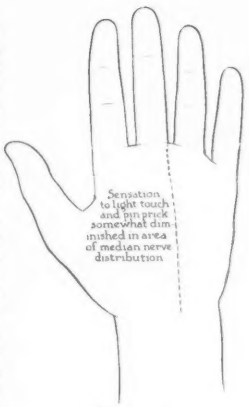


Fig. 41c.

the bridge of connective tissue and overlaps the two segments sufficiently to shorten the lengthened tendon, suture is more easily carried out, but a considerable mass of tissue is left under the thin skin of the distal phalanx which may interfere with healing of the skin and leave a tender and unsightly swelling at the site of suture.

In excising the bridge of connective tissue that has formed between the ends of the ruptured tendon, care must be taken to leave the greatest length possible attached to the distal phalanx. It is always difficult to be certain that the sutures inserted in the thin distal segment of tendon will not cut through and release their hold on the distal phalanx. The larger the slip of tendon left attached to the distal phalanx the less likely is this to happen.

In the after care of such injuries we have found it wise to splint the affected finger in complete extension or slight hyperextension at the distal interphalangeal joint for a period of two and one-half or three weeks. For this purpose the familiar baseball splint of Lewin is very useful.

RÉSUMÉ OF CASES OF DIVIDED NERVES AND TENDONS

Since March, 1916, we have had the opportunity of operating upon 170 patients with division of the nerves and tendons of the hand.[25] Ninety-seven of these were from the service of Drs. Kanavel, Loyal Davis, Mason, and Koch at Wesley Memorial Hospital; 57 from the service of Drs. Mason and Koch at Passavant Memorial Hospital; and 16 from the service of Dr. Koch at Cook County Hospital. In 70 cases tendons alone were divided; in 31 cases nerves alone; in 69 cases both nerves and tendons.

In 134 cases the injury involved the volar surface of the forearm, wrist, or hand; in 37 cases the dorsal surface. (In one patient the dorsal surface of the right hand and volar surface of the left were involved in the same accident). The hand involved, the approximate location of the various injuries, the relative frequency of injury in different locations, and the relative frequency of associated nerve and tendon injury in different locations are indicated in Figures 34 to 39. The striking fact illustrated by these diagrams is the frequency of involvement of the volar surface of the wrist, the extent of such injuries, and the almost constant association of multiple ten-

[25] This does not include a group of 15 cases of nerve and tendon division in which it was impossible to approximate the divided tendons and in which the defects were bridged with tendon grafts.

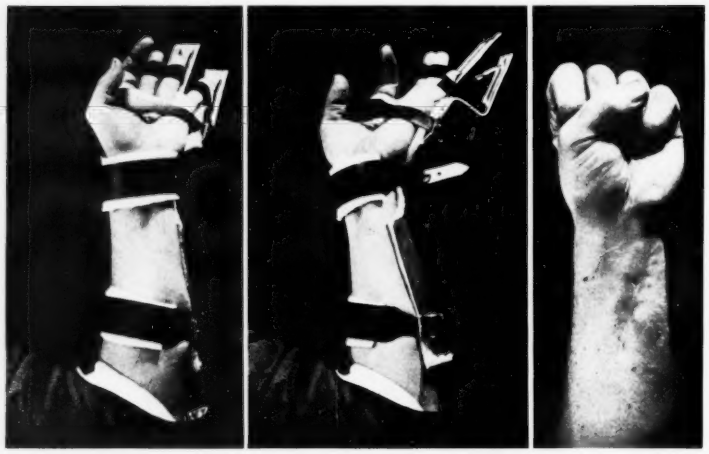


Fig. 42. Division of ulnar nerve and blood vessels, flexor carpi ulnaris and superficial flexors of four fingers; immediate ligation of blood vessels and suture of divided nerve and tendons under gas and ether anæsthesia. Low grade infection of wound with sinus formation persisting for 6 months after operation. Result 8½ months after operation.

don divisions with division of the median or ulnar nerve or both.

The age of the patients varied from 12 months to 60 years. Fifteen were between 1 and 5 years of age; 18 were in the first decade of life, 22 in the second, 63 in the third, 38 in the fourth, 22 in the fifth, and 6 in the sixth; the age of one is unknown.

A brief discussion as to the immediate cause of injury, the immediate treatment rendered and the immediate results obtained may be of some interest. In 166 cases the cause of injury was recorded. In 46 cases the injury resulted from a glass cut, and in the majority of these cases the patient had fallen and pushed his hand through a glass door or window. In 25 the injury resulted from an automobile accident, and in the majority of such cases it was stated that the wound was caused by broken glass from a windshield or car door. In 23 cases the injury was due to a knife cut, a stab wound, or razor wound. In 11 cases the injury resulted from a fall on a bottle, a glass tumbler, or a cup with collapse of the object and a resulting penetrating wound. In 9 cases the injury resulted from collapse of the porcelain handle of a water faucet with subsequent laceration and penetration of the palm by a sharply pointed or jagged fragment of the handle. In 12 cases tendon

Fig. 43. Division of median nerve, long flexor tendons of thumb, index and middle fingers; immediate tendon suture elsewhere; primary union; unsatisfactory functional result with inability to flex thumb and index completely forcefully. Secondary nerve and tendon suture 5 ye after injury. Result 17 years after secondary operation

division was the result of subcutaneous rupture; in 2 cases the flexor tendon of a finger was involved, in 10 cases an extensor tendon opposite a distal interphalangeal joint. Other causes included gunshot and bullet wounds, injuries from rip saws or circular saws, lacerations from jagged steel fragments, wire, sharp edges of zinc and tin, and crushing injuries.

Twenty-two patients were seen by us within from 20 minutes to 25 hours of the injury, and were operated upon immediately; two other patients, one seen 36 hours after injury, and one 48 hours after injury were also operated upon immediately. Of these 24 patients the operative wound healed by primary union in 15 cases; wound infection developed in 7 cases; 2 patients did not return after operation, and no record of the postoperative course in these 2 cases is available.

The 7 cases in which wound infection developed after immediate operation deserve particular consideration, for it was primarily because of the infection which took place in these cases and the severity and duration of the infection in 4 cases (Cases 1, 3, 4, 5) that we were forced to recognize the danger of immediate operation for divided nerves and tendons and that we have since laid so much stress on the importance of delaying repair of divided nerves and tendons unless one is certain that the wound is clean.

CASE 1. F. P., Wesley Memorial Hospital, 111566, April 10–May 6, 1924 (Fig. 40).

This patient, a bottle inspector 23 years of age, sustained a cut across the volar surface of the thumb at the level of the metacarpophalangeal joint from a broken glass jar April 8, 1924. He received treatment from a physician for two days and was then sent to the hospital because of inability to flex his thumb at the interphalangeal joint. He was operated upon under local anæsthesia shortly afterward, approximately 48 hours after the injury. The somewhat ragged skin wound was enlarged, the ends of the divided flexor pollicis longus brought together with silk sutures and the skin wound loosely closed with silkworm gut and skin clips. Warm wet dressings were applied to the hand continuously after operation.

The morning after operation, April 11, the patient's temperature had risen to 102 degrees and it was noted that there was "œdema, redness and tenderness, particularly about the wrist and on the radial side. No pain on extension of the little finger; some pain and wincing on extension of the index and middle fingers"; on April 12 "swelling of the wrist a little more marked"; on April 13 "swelling of the wrist, forearm and dorsum of hand more marked, redness and exquisite tenderness on radial side of dorsum of wrist." Between April 11 and April 14 the irregular temperature ranged from 98.6 to 103 degrees, reaching the latter point on the afternoon of April 14. April 15, under nitrous oxide anæsthesia, the radial bursa was opened by extending the operative incision upward for 3 inches along the radial side of the forearm. A thin, sanguino-purulent discharge was evacuated, which showed a pure growth of staphylococcus (the report does not say whether albus or aureus) on culture. The following day it was noted, "Thin seropurulent discharge around rubber tissue drain. Patient feels much better; slept for first time last night."

The infection gradually cleared up and the patient left the hospital May 6, 26 days after operation (tendon suture) with the wound healing, but still requiring dressings.

CASE 2. A. H., Wesley Memorial Hospital, 113096, 114522, July 1–30, 1924; September 18–23, 1924.

This patient, a 33 year old carpenter, received a long, oblique, deep cut of the left palm and wrist from a rip saw, June 30. He was taken immediately to a hospital where the injury was treated and the wound sutured under ether anæsthesia.

The following day he was transferred to Wesley Memorial Hospital and operated upon under gas and ether anæsthesia shortly after admission. The wound, extending from the cleft between the little and ring fingers to the base of the thenar eminence, was opened widely; the median nerve, all the long flexor tendons of thumb and fingers and the first metacarpal bone had been divided; no attempt had been made at operation the day before to repair these structures. The tendons and nerve were united, and the hand splinted so as to immobilize the first metacarpal. The operation required 2 hours, 5 minutes. Warm wet dressings were applied to the hand at the close of the operation and maintained continuously for 48 hours.

The afternoon following operation the patient's temperature rose to 101 degrees; thereafter it gradually receded, reached normal on the third postoperative day, and did not rise above 99.2 degrees thereafter. Although he complained of some pain in the hand there was very little postoperative swelling, and for some days it appeared as though healing were taking place without infection. On the tenth postoperative day, July 11, a slight wound discharge appeared between the little and ring fingers; two sutures were removed from this area and some thin seropurulent discharge escaped. The following day the dressings were fairly well saturated, and it was noted that there was separation of the skin edges along almost the entire extent of the wound. Bridges of adhesive were placed across the incision to prevent further separation, the wound was carefully dressed each day and by July 19 there was little

wound discharge. July 25 it was noted that there was still slight wound discharge at the base of the thumb. July 28 the wound was dry; still œdema on the dorsum of the hand 29 days after operation.

The patient left the hospital July 30, and returned daily for physical therapy. Sometime after leaving the hospital (the exact date is not recorded) a sinus appeared at the distal end of the wound between the ring and little fingers. Because of this he re-entered the hospital September 18. The sinus was curetted and warm wet dressings applied for 48 hours. He left the hospital September 23 and the wound discharge ceased completely shortly afterward.

CASE 3. U. S., Wesley Memorial Hospital, 124311, 133054. March 31–May 24, 1926. July 26–August 1, 1927.

This patient, a 16 year old piano student, was admitted to the hospital at 11 p.m., twelve hours after an automobile accident in which she had received a glass cut across the volar surface of the left wrist. The divided ulnar artery had been ligated with silkworm gut immediately after the injury. Operation was performed under local anæsthesia the following morning, April 1, just twenty-four hours after the accident. There was little swelling about the site of injury at the time of operation and no evidence of infection in the open wound. The median nerve and all the flexor tendons over the volar surface of the wrist except the deep flexor of the little finger had been divided. All were isolated. The wound was enlarged by a longitudinal incision, and the divided structures carefully sutured.

Twenty-four hours after operation the patient's temperature had risen to 103.6 degrees and her pulse to 140. She complained of some pain in the forearm. The following day the fever and rapid pulse persisted, the forearm was very painful, and considerably swollen. The skin clips and a part of the dermal sutures were removed with the escape of a small amount of thin fluid. Culture of the fluid showed a mixed growth of staphylococcus albus and a short chain streptococcus. After removal of the sutures massive warm dressings were applied to the entire upper extremity.

During the five days following, the patient was seriously ill with high fever, vomiting, and obvious toxæmia. Her temperature ranged from 99.4 to 102.4 degrees, her pulse from 112 to 144. On the seventh day after operation the symptoms of acute infection began to subside and as they did so wound discharge became more profuse and necrosis of the tissues about the wound became apparent. Although by this time all sutures had been removed and the wound lay widely open, extension of the infection both upward and downward gradually took place, necessitating incision and drainage of the upper forearm April 17, of the thenar space April 23, and of the lower part of the arm above the elbow May 4. May 5 because of considerable loss of blood the day before and because of her critical condition she was given a transfusion of 700 cubic centimeters of citrated blood.

From that time on she improved rather rapidly and left the hospital May 24, eight weeks after the injury, with the hand and forearm nearly healed.

During the summer of 1926 she received intensive physical therapy with some improvement in mobility of the fingers.

She was readmitted to the hospital July 26, 1927, a year later. At that time there was definite hypoæsthesia throughout the area of median nerve distribution. The thumb was held in flexion at the interphalangeal joint. The other fingers could be completely flexed, but not completely extended (Fig. 41). At operation July 27, it was found that the suture of the median nerve and the flexor pollicis longus had given way and these structures had become firmly adherent to one another and to the surrounding tissues. The deep tendon to the index finger had healed in a lengthened position. The tendon of the thumb and the median nerve were freed and the ends of each united by end-to-end suture. The deep tendon of the index finger was shortened.

The range of movement of the hand and fingers and the persistence of atrophy of the thenar muscles August 8, 1930, are shown in Figure 41. At that time sensation to light touch and pin prick was present over the entire median nerve area, but somewhat diminished.

CASE 4. W. F., Wesley Memorial Hospital, 127271, 129004, 129815. September 9–16, 1926; December 20–23, 1926; February 8–12, 1927. (Fig. 42).

This patient, a clerk of 20 years, fell as he was leaving his place of work at 5 p.m. September 9, 1926; his left arm shot forward as he fell and crashed through a plate glass door. He was taken to Wesley Memorial Hospital immediately and operated upon shortly after admission under gas and ether anæsthesia. The record does not state the exact time of operation, but does state that he returned from the operating room to the ward at 7:30 p.m.

At operation it was found that the ulnar nerve and blood vessels, the flexor carpi ulnaris, and the superficial flexor tendons of the four fingers had been divided; the ulnar vessels were ligated, the divided nerve and tendons sutured.

The morning after operation the patient's temperature was 100.4 degrees; it fell to 99 degrees the following day and remained normal after the third day. On September 14 it was noted by Dr. Mason, "Some discharge from the wound. This is due, I think, to the tincture of iodine which was swabbed liberally in the wound at the time of operation. Temperature normal." On September 16 the patient left the hospital. There was "slight drainage from the wound, not purulent." The exact date of healing is not recorded.

December 20 the patient was readmitted to the hospital because the wound had opened spontaneously several weeks after healing had taken place, and discharge from the resulting sinus had persisted. On admission there were several apparently superficial discharging sinuses along the operative incision.

A drop or two of yellow pus could be expressed from them. These sinuses were excised under gas and ether anæsthesia, and three pieces of knotted suture material removed from the depth of the rather superficial wound. The wound was loosely sutured. The patient left the hospital on the third day.

February 8, 1927, he was readmitted to the hospital with a small discharging sinus still present at the site of the former operation. Because he had a rather severe acute upper respiratory infection no operative procedure was carried out at that time and he left the hospital 4 days after admission. The record does not state the exact time of healing, but shows that it was complete April 23, 1927, at the time the photographs (Fig. 42) were taken.

Case 5. H. D., Wesley Memorial Hospital, 130406 (Fig. 5).

This patient, a girl of 8 years, sustained a jagged wound of the dorsum of the left hand from a broken mirror, March 12, 1927. She was taken immediately to a doctor who dressed the hand and advised hospital care.

She was admitted to the hospital 2½ hours after the injury and operated upon under ether anæsthesia an hour later. The wound lay directly over the middle of the metacarpus; a triangular flap of skin, with its apex above and its base just proximal to the metacarpophalangeal joints, had been torn downward; the extensor tendons of the index and middle fingers had been completely divided, that of the ring finger partially divided. The wound was cleansed in the operating room with soap and water, ether, alcohol, and picric acid solution. The tendons were sutured with silk, the wound edges loosely approximated with interrupted sutures and some strands of silkworm gut left in the wound for drainage. The operation, according to the anæsthetist's record, required thirty minutes. Warm wet dressings were applied to the hand at the close of the operation and maintained for the next 9 days.

March 14, 48 hours after operation, the patient's temperature had risen to 102 degrees. The following day, March 15, there was considerable swelling of the flap; three sutures were removed from the skin and a small quantity of seropurulent fluid escaped from the wound. On the fourth day, March 16, a Carrel tube was inserted into the wound and instillation of 3 cubic centimeters of Dakin's solution every 3 hours begun. The warm boric dressings were continued as before. March 18, "considerable pus was expressed from the wound"; the patient's temperature had gradually receded from 102 to 100 degrees. March 20 the instillation of Dakin's solution was discontinued. March 22 the continuous warm wet dressings were discontinued, and instead the hand was soaked for 15 to 20 minutes twice daily in warm sterile boric solution.

The infection cleared up very slowly. April 15 a small localized accumulation of pus under the healing flap was incised, and continuous warm boric dressings again applied for 2 days. The wound was almost healed when the patient was discharged from the hospital May 3, 1927, 7½ weeks after admission. In spite of the prolonged suppuration and the prominent scar on the dorsum of the hand the functional result was excellent (Fig. 5).

In the last case the possibility of chemical injury of the tissues about the wound comes into consideration, as mirror glass injuries in other cases in our experience have been followed by persistent suppuration, with slow but progressive necrosis of the surrounding tissues. Whether it was a factor in this case is, of course, purely conjecture.

Of the 146 patients who came to us for secondary treatment an immediate closure of the superficial wound alone had been carried out elsewhere in 42 cases. In 22 of these cases the wound healed by primary union; in 6 cases there was a slight wound discharge for from 2 days to 3 weeks. In 10 cases suppuration developed. In 4 cases there is no record as to the immediate result.

In 54 of the 146 cases immediate nerve and tendon suture had been carried out elsewhere. In 28 of these the wound healed by primary union; in 8 a low grade infection developed; in 14 suppuration and tissue necrosis took place and complete wound healing was delayed for from 3 to 10 weeks from the time of injury.

In 146 of our cases in which secondary operation was performed, i.e., all the cases except the group of 24 operated upon by us shortly after the injury, the operative wound healed by primary union in 119 cases. In 3 cases there is no record as to the result as far as infection is concerned. In 4 cases failure of primary union was due to slow necrosis either of a longitudinal strip of skin along the line of incision or of a small transverse section of skin centering at the site of the original transverse wound. This necrosis we believe resulted from impairment of the blood supply of the skin flaps, either because of scar tissue formation following the original injury, because of trauma during the operation, because of excessively thin skin flaps, or because the skin was sutured under excessive tension.

In 20 cases of secondary operation failure of primary union was due to infection. In 8 of these infection was described as "slight, low grade, superficial infection of center of

wound, etc.," and cleared up in from 10 to 24 days after operation. In 4 infection was slight but persistent or recurrent for from two and one-half to six months after operation, and subsided when some unabsorbed suture material was extruded. In 8 suppuration developed, with some necrosis of superficial and deeper tissues, and complete healing was delayed for from four to eight and one-half weeks after operation.

The incidence of postoperative infection has become steadily less. In 63 out of 71 cases operated upon between June, 1929, and July, 1932, the operative wound healed by primary union. In 3 of the 8 which did not heal by primary union there was slow necrosis of a strip of skin along the line of operative incision, without evidence of infection until this necrosis took place; in 3 the infection was slight and cleared up in from ten to eighteen days after operation; in 1 infection was apparently due to organisms of low virulence, but a slight discharge persisted for eight weeks after operation; in 1 frank suppuration and sloughing of tissues took place and healing did not take place until eight and one-half weeks after operation. In spite of the fact that we have not yet succeeded in eliminating infection as a postoperative complication we believe that it is avoidable and that it can be eliminated by watchful care at every stage in the operative treatment, from the beginning of the preparation of the hand for operation to the time of removal of sutures.

RESULTS OF SUTURE OF DIVIDED NERVES AND TENDONS

A number of factors conspire to make difficult an appraisal of the results obtained in a group of cases such as that under discussion: the ambition of the workman to secure a good result; the desire of the patient to show a satisfactory result, or, occasionally his desire to minimize the degree of improvement because of the possibility of securing additional compensation; the location and extent of the original injury; the interval of time elapsing between the injury and the operation; the amount of scar tissue formation present at the time of operation, which is usually directly dependent upon the extent and character of the infection which followed the original injury; the time that has elapsed between the operation and the last examination—an essential consideration in the case of nerve suture; and the faithfulness with which physical therapy, exercise, and use of the injured hand have been carried out. Because of these many factors affecting each case in varying degree it is almost impossible to classify the results obtained as excellent, good, etc. If a patient secures a usable and useful hand after a severe injury and serious infection that have resulted in complete loss of function for a year or more, such a result can fairly be considered excellent, though the hand may be far from perfect as compared with the normal. On the other hand if one secures a result somewhat less than perfect in a case in which every condition has been favorable, it can not truly be considered an excellent result. The results of nerve suture particularly are difficult to interpret.[26] The rapidity with which overlap from adjacent nerves develops in the area supplied by the divided nerve varies in different individuals and, as has been stated above, this one factor, emphasized particularly by Pollock, is a constant possible source of error in interpreting the findings present after nerve suture. The patient's interpretation of the signs of returning sensation is often misleading, and one must be conservative about drawing conclusions simply from a patient's statement (Fig. 14).

We have not been able to secure results such as Bunnell has obtained—return of sensation at the rate of a phalanx a month after suture of the digital nerves—nor have we seen return of function appear as rapidly in the majority of cases as is suggested by most writers to be the normal expectancy. On the other hand we have seen progressive improvement taking place for a long period after operation and continuing far beyond the time ordinarily considered as marking the limit of possible improvement. We say ordinarily considered, although we do not know of any accurate statements concerning the length of time during which improvement can be expected to continue after nerve suture. In this

[26] "The prognosis of nerve suture is . . . a matter of great complexity, and the term 'recovery' is so relative as almost to cease to have a meaning." Souttar and Twining.

connection the following case report is of particular interest, and especially so because the patient is a physician and accustomed to making accurate observations:

R. A., Wesley Memorial Hospital, 50951 (Fig. 43). This patient, a 23 year old medical student, at the age of 17 plunged his right hand through a glass window and divided the median nerve and long flexor tendons of thumb, index, and middle fingers. The tendons were sutured soon afterward; the wound healed without infection. After the accident complete anæsthesia in the median nerve area persisted, the skin became somewhat atrophic, and gross changes in appearance and brittleness appeared in the nails of thumb, index, and middle fingers. Atrophy of the thenar muscles was slow but progressive. There was impairment of flexion of the thumb and complete loss of flexion of the index finger.

December 19, 1914, 6 years after the accident, nerve and tendon suture were performed by Dr. Kanavel. At operation it was found that the proximal segment of the median nerve had become united to the distal segment of the flexor pollicis longus. Nerve and tendon were separated and an anatomical restoration carried out. The patient was discharged from the hospital 5 days after operation; postoperative recovery was complicated by persistent serous drainage from a small sinus; complete healing took place after a piece of unabsorbed catgut was removed from the wound.

January 8, 1932, the patient stated: "Sensory change following the operation was very slow in appearing. There was very little change at all during the first year, but progress in both sensation and cutaneous trophic changes was progressive after three years; in fact I believe that there was as much change after three years as there was before.

"The hand gradually improved year by year and apparently has improved not only in appearance but in sensation even in the last few years.

"As you know from the last examination there is now very little difference in the palmar surface of the two hands and the only sign of trophic disturbance is that the skin along the ulnar side of the thumb nail is rough and indurated. Otherwise the nails appear practically normal. There are still a slight perceptible roughness and lack of markings in the radial one-half of the palm. The thenar atrophy has never improved. All function is present in the hand and I am able to flex the fingers completely with the fingers in full extension at the metacarpophalangeal joints. I operate with this hand, use the scalpel, and have normal use in the fingers (Fig. 43) except that I do miss the opponens action."

Another fact should be recorded which concerns particularly the results of tendon suture, but which applies to patients with nerve suture as well. Division of tendons and nerves is followed by retraction and atrophy of the divided tendons and muscles and atrophy of the muscles innervated by the divided nerves. Its extent depends to a considerable degree on the interval elapsing between the injury and the reparative operation. When the divided tendons are united movement is again made possible, but such movement at first is often sluggish and definitely limited. With use, however, even though it is minimal at the outset, the atrophic process is arrested and the cycle is reversed. Use of the part stimulates blood supply and muscle and nerve regeneration. Muscle and nerve regeneration and return of motor nerve function permit a little greater use and movements of greater range and power. In other words, the reversed cycle becomes a beneficent one instead of a vicious one, and each phase re-enforces the other. The result is that patients who have gained only a limited restoration of function at the end of a few months often return after a year or eighteen months with a surprising and sometimes unexpected degree of improvement.

We believe we can say fairly that the results of operation have justified the efforts, the time and money which the patients have expended in the attempt to secure improved function, and, secondly, that our results have definitely improved with increasing experience and increasing efforts to secure healing by primary union and without infection. A few patients have secured a perfect functional result and it is such cases particularly that encourage us to keep on trying to perfect our technique to such a point that we can in fairness hold out to every patient with division of nerves and tendons the reasonable assurance of a satisfactory result.

SUMMARY

In the treatment of divided nerves and tendons a careful examination of the patient before operation to determine the degree and extent of injury is of primary importance. To choose the wisest plan of immediate treatment requires careful consideration of a number of factors; unless one can be reasonably certain that the wound is free from infection it is far better to leave the superficial wound

open, or suture it loosely and permit it to heal, than to run the risk of opening tissue spaces widely and bringing about widespread extension of a virulent infection.

When operation is performed, whether immediately or at a later date, every effort should be made to ensure healing by primary union, for in securing a successful result nothing in the way of accurate apposition, careful suture or painstaking postoperative care can compensate for failure to secure wound healing without infection.

In the technique of operation gentleness in the handling of tissues, accurate apposition of tendons, end-to-end apposition of healthy nerve ends, the use of fine suture material, and the employment of a bloodless field during the operative procedure are important details. Properly designed splints, and skilfully applied physical therapy are important and helpful adjuncts in securing successful results in the shortest possible period of time after operation.

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OBSERVATIONS ON THE MECHANISM AND SIGNS OF SEPARATION OF THE PLACENTA

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SINCE 1914 the author has been practicing as a matter of routine a method of facilitating separation and delivery of the placenta, which has met all indications, although, since it involves considerable inconvenience in maintaining asepsis, it is now employed only in cases in which there is lack of contraction of the uterus, bleeding, or adherent or retained placenta. This method (2) was original with him and was named by him the "dorsosquatting" posture, suggested by the posture assumed at stool by primitive peoples (3). It is an evolution of the one called exaggerated lithotomy position, which DeLee advocated in cases of inefficient pains and in moderately contracted pelves, at the end of the first and the beginning of the second stages of labor (1). Figure 1 shows the dorsosquatting posture, with pelvis suspended; Figure 2, the dorsosquatting posture in action during the third stage of labor. In this all the pelvic diameters are increased, the rectus muscles contract and harden, intra-abdominal space is diminished, and intra-abdominal pressure is increased. Uniform continuous pressure on the uterus causes correspondingly regular contraction and retraction. The sinuses empty, the blood vessels regain their tonicity to some extent, and the uterus thus contracts, retracts, and remains firm. This is accomplished in 6 or 7 minutes but the posture is maintained for a few minutes longer, at which time the placenta is easily expelled intact and with comparatively little free loss of blood. The posture is continued for another short period to insure the contraction and involution of the uterus.

SIGNS OF SEPARATION OF THE PLACENTA

Thus far, the only reliable sign indicative of separation of the placenta is a firmly contracting uterus, all other so called signs being only theoretically, incidentally, or occasionally true. Dr. Morris Leff, from observations on a thousand cases, finds that the placenta separates completely soon after the uterus is reduced in size and that separation occurs from 2 to 5 minutes after tying the cord, or a maximum of 8 or 9 minutes after delivery of the fetus. He comes to this conclusion after digital examination of the vagina when he finds the placenta at the level of, or somewhat lower than, the external os.

The author considers the placenta separated only when it is lying freely in the vagina. Otherwise, it is only partly separated, being still sustained by part of the placenta or the undetached membranes, and these membranes are almost as likely as the placenta proper to give trouble both during and after delivery. Even in the Schultze method, when the bulk of the placenta can be felt at the lower edge of the cervix or upper end of the vagina, it may still be upheld by undetached membranes or by all or part of its normally most adherent position—the circular edge. Even the size of the placenta thus palpable is but relative, since at this time all the diameters of the uterus are diminished and the passive lower segment, drawn up to the higher level, exposes to palpation a larger area of placenta regardless of the extent of separation, a condition more marked in low implantation of the placenta. This area may be still further increased by the resiliency inherent in the placenta, which causes it to accommodate itself to a contracting uterus without separation but with the formation of a convex "bulge."

Recent observations show that in normal cases the placenta presents itself at the level below the dilated external os usually after the third, fourth, or fifth regular contraction, exclusive of the initial contraction following delivery. Occasionally, the placenta will separate after the first contraction if this is strong and prolonged. It descends and becomes tense with each contraction and rises and

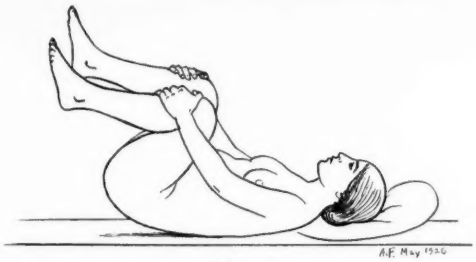

Fig. 1.

Fig. 2.

softens during relaxation. If the contractions are more pronounced than the relaxations the placenta will progressively descend without rising and softening during the intervals. Normally the internal os or contraction ring forms immediately after expulsion of the placenta, to the extent of diminishing the lumen of the lower segment of the uterus to a diameter varying from one-half to one and a quarter inches, with the soft, thin, and relatively shrunken cervix below and in front of it. Soft and ill-defined ring formation before the descent of the placenta is not infrequent, but if expression is not forced or hurried it will yield sufficiently to allow its passage and then immediately recontract. Two cases were observed in which the cervix, consisting at this time normally of a loose, soft, circular flap, before the placenta presented itself at the external os, assumed the form of a number of firm, irregular concentric convexities in horizontal position making up the cervical canal. With the expulsion of the placenta the cervix was immediately drawn up with the convexities in perpendicular concentric position facing the uterine canal, the vaginal surface thus assuming the aspect of normal cervical mucosa and the external os admitting one finger. Since in neither case could the examining finger feel the usual contraction ring with the soft cervix below and in front of it, the occurrence might be explained on the basis of atypical ring or external os formation.

IRREGULARITIES AT THE PLACENTAL SITE AND POSSIBLE MECHANISM OF ITS OCCURRENCE

In January, 1920, while waiting for signs of separation of the placenta, the author noticed an irregular area on the uterine wall, located sometimes on the fundus, sometimes on the anterior, and sometimes on the posterior wall, having the appearance of multiple shallow subserous fibroids. Further observations showed that in the vast majority of cases, except in those in which there was complete hardening of the uterus, this sign made its appearance from 10 to 15 minutes after the birth of the fetus, which is a little less than the average time it takes for the placenta to separate. While the presence of this sign may not always be an evidence of complete separation of the placenta, it does imply a maximum amount of detachment and, more important still, a higher degree of contraction and retraction, making it safe at this time to attempt expulsion. No difficulties were ever encountered when attempts at expression were made after the appearance of this sign. In the majority of over two hundred cases in which the separation of the placenta was studied by means of palpation with fingers in vagina to a height above the external os, the irregularities appeared after the placenta was lying freely in the vault of the vagina. These irregularities can form only at the placental site, which at this time is the most vascular and therefore the most yielding part of the uterus. The following attempt has been made to explain the mechanism of their occurrence.

The pregnant uterus may be compared to a syringe with yielding or collapsible wall, minus an opening for the nozzle and with a piston of two parts, the fetus and the placenta. With the gradual dilatation of the cervix, beginning at the establishment of the first stage

of labor, the vacuum principle initiated by the contractions and relaxations of pregnancy is set into play. The tendency of the uterus to contract obliterates the vacuum caused by relaxation and forces the fetus downward. The following relaxation creates a new vacuum, forcing the fetus upward, but to a less degree than the preceding one and the succeeding contraction in its turn continues the downward course of the fetus. When the uterus is sufficiently drawn up above the presenting part to cause this vacuum to become inefficient, the abdominal muscles and intra-abdominal pressure readily supplement this deficiency. With the expulsion of the fetus the major part of the piston disappears and the uterus contracts, obliterating the vacuum space. The placenta and membranes now become puckered or partly separated, with resultant vacuum formation and with the aid of inherent contraction, retraction, and relaxation and retroplacental blood formation these vacua cause, after the placenta is sufficiently separated and the sinuses obliterated by means of compression and aspiration, an irregular caving in of the placental site.

The following observation in a general way proves the reality of the syringe vacuum principle which is operative during pregnancy and labor:

Mrs. A. E., 1-para, full term; measurements and pregnancy normal; delivered of twins on March 14, 1930, at Hunt's Point Hospital. First infant, occipitoposterior, was delivered with forceps. The second, larger infant presented too high for forceps application. With patient still anæsthetized podalic version was performed. When legs presented at vaginal outlet, patient's respiration became loudly stertorous and deep, and with each respiration the fetus progressively descended until it reached the nipple line, when patient's respiration became more normal, and spontaneous progress ceased.

In 2 later cases of breech extraction delivered in private homes the phenomenon was absent in the first, which was a very large child, and present in the second, which was a 6 pound child. There is reason, therefore, to believe that in the absence of relative disproportion between the parturient outlet and the child this mechanism or its tendency should be manifest.

The same tendency is felt, though in reversed order, when attempts are made in primiparæ to stretch the vagina with the fist, previous to operative interference. As soon as the fist passes the hymenal sphincter the upward suction with each respiration can be distinctly felt.

It has further been observed in a number of forceps deliveries at the time the vaginal sphincter engaged the largest diameter of the head, if the forceps were then used simply as a means to prevent its recession, the respirations became deep and stertorous and with each respiration progress was made until the sphincter grasp was relieved.

Another illustration of the vacuum principle, which casts light on the mechanism involved in the maintenance of fetal heart action and circulation is supplied by the cutting away of a portion of the cord just below the ligature applied before it is severed, and the squeezing out of the blood, starting at the placental end. The cord will immediately refill with the placental blood. This may be repeated for as long a period as 20 minutes and the cord will promptly refill, regardless of the position in which it is held.

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POSTOPERATIVE PULMONARY COMPLICATIONS

I. A Statistical Study Based on Two Years' Personal Observation[1]

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THIS study of postoperative pulmonary complications occurring on the General Surgical Services of the Massachusetts General Hospital was begun in the fall of 1929. It was made from the standpoint of the internist and was undertaken at the suggestion of Dr. L. S. McKittrick of the Surgical Service. After a preliminary study of the hospital records, it was found that figures from these records were unsatisfactory, since the milder pulmonary complications, as a rule, were not included in the discharge diagnoses, and adequate descriptions of the complications were not recorded. For example, only 44 per cent of the complications occurring in 1929 were listed in the discharge diagnoses. (The remainder were found by a study of the bi-monthly surgical reports or the hospital records, and by personal observation.) It was apparent, therefore, that really satisfactory statistics could be obtained only by personal observation during the period for which figures were to be reported. Accordingly, the author observed personally practically all of the postoperative pulmonary complications in 1930 and 1931, and, in addition, studied a great many cases of the type in which complications most frequently develop, although they did not actually occur. The observations have been made carefully, and the figures have been compiled accurately, so that although most of the conclusions are not new, they are based upon a series of cases sufficiently large to make the percentages reliable and they emphasize points which we believe essential to an understanding of the problem.

The nature of the process. The study has been confined to the type of complication which occurs in the first three or four days after operation and is almost always accompanied by fever, leucocytosis, cough, and purulent sputum. Cases of proved pulmonary embolus, exacerbation of pulmonary tuberculosis, empyema, and so forth, have been excluded. The type of complication studied has been diagnosed in the literature as bronchopneumonia, "pneumonitis" or collapse (atelectasis). In the series here reported, a certain number of cases have run the clinical course and presented the physical and X-ray signs of a true bronchopneumonia. The percentage of these cases is small; nevertheless, the group is important since it includes most of the fatal cases. There is also a much smaller number of cases which can be diagnosed, clinically and by X-ray, as typical "massive collapse" produced by occlusion of a large bronchus by exudate and clearing quickly when the "plug" is expelled by cough. Between these two definite entities lies a large "intermediate" group of cases which are more difficult to classify.

The lesion in this intermediate group is not "pneumonia" in the medical sense, since it runs a much shorter and less toxic course. Whipple (6) has called it "pneumonitis," using that term to mean a "pneumonia" in which the alveolar exudate is caused by a relatively avirulent pneumococcus, is lacking in fibrin, and is therefore quickly absorbed. Cutler has regarded it as embolic pneumonia, but the onset is much earlier than in most proved cases of pulmonary embolus, and the symptoms and signs are so different that his theory is difficult to prove. Coryllos has championed the collapse theory, maintaining that the steps in the development of postoperative "pneumonia" are bronchitis, obstruction of a bronchus by exudate, atelectasis due to bronchial obstruction, and then pneumonia developing in the collapsed area.

The differential diagnosis is, then, between low-grade bronchopneumonia (better termed "pneumonitis") and lobar or lobular atelectasis. A study of X-rays and physical signs has assisted in the attempt at differentiation.

Dr. G. W. Holmes, of our X-ray Department, is of the opinion that those cases in which the X-ray shows increased density with a definite diminution in lung volume on the affected side should be diagnosed as collapse.

[1] A study made on the Surgical Services of the Massachusetts General Hospital by the author, a member of the Medical Service.

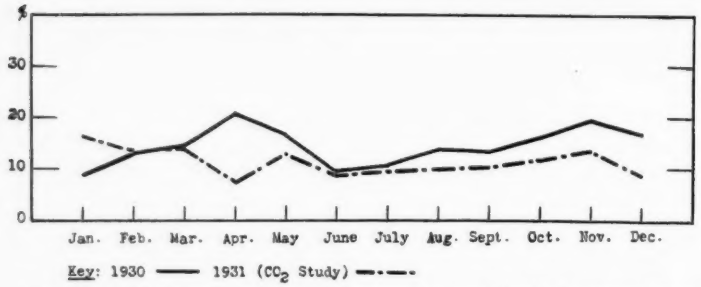

Fig. 1. Monthly percentage of pulmonary complications following laparotomies and hernia operations in 1930 and 1931 (CO_2 study).

This reduction in volume is shown in the typical case by displacement of the mediastinum, elevation of the diaphragm, downward inclination of the ribs, and narrowing of the intercostal spaces. All of these signs of collapse are not present in every case. Displaced mediastinum or elevated diaphragm may occur alone. Dr. Holmes calls attention to the danger of making a diagnosis from an X-ray film taken at full inspiration because, at this phase of respiration, displacement toward the affected side is present in consolidation as well as in atelectasis. In a true atelectasis, displacement toward the side of the lesion is present on expiration as well as on inspiration, while in consolidation this displacement is present on inspiration only. Care must be taken also to exclude those films in which X-ray signs might be due to exposure at complete expiration (5). Further, it must be remembered that in a bilateral process of any sort there is usually no displacement of the mediastinum.

TABLE I.—CLASSIFICATION

	1928	1929	1930	1931
Collapse	16	25	87	113
"Bronchopneumonia"	72	116	152	74
Total	88	141	239	187
Bronchitis	—	142	92	111

The classification of cases in Table I is based largely on X-ray evidence of diminished lung volume. It is interesting to note that as the years have gone on and knowledge of the process has increased, the diagnosis of atelectasis has become more frequent, so that whereas in 1928 less than one-fifth of the total complications were diagnosed as collapse, in 1931 two-thirds of the cases were so recorded. Of the 200 cases classified as collapse in the years 1930 and 1931, 78 could be diagnosed on the basis of physical signs alone and the other 122 required X-ray evidence of diminished lung volume. (To complete the figures, the number of cases of bronchitis without parenchymal involvement has been added to Table I.)

The study of *physical signs* has become increasingly important because of the stress which has been laid upon bronchial obstruction as a factor in the production of postoperative pulmonary collapse. Dr. Frederick T. Lord, of this hospital, has made a study of the physical signs which occur with bronchial obstruction and has repeatedly shown that obstruction of a bronchus from any cause gives dullness and absent or much diminished breathing (without bronchial breathing) and absent or diminished voice (without egophony) and diminished whisper and tactile fremitus. If, however, the bronchial obstruction is removed and the atelectasis persists, the signs change and are those of consolidation. It is especially important to call attention to the signs of atelectasis with open bronchus because many authors have assumed that when bronchial breathing appears over a collapsed area, a true pneumonia has unquestionably developed.

If one is to accept the theory that most postoperative pulmonary complications are atelectases due to occluded bronchi, the first signs should be very much diminished or absent breathing which, when the bronchus is open, should change to bronchial breathing and the other signs of consolidation (unless the lung expands immediately). In some cases

(16 of our 1931 series), this progression of signs did take place and it is possible that very frequent examinations started soon after the operation would show it in most cases. Actually, in 1931, 140 of 187 pulmonary complications showed definite changes in breath sounds. Of these, diminished breathing was the first change noted in 66 cases, and bronchial breathing was the first change in 74 cases. These groups ran practically the same clinical course and it was impossible to say that diminished breathing at the first examination indicated collapse, while bronchial breathing at this time indicated pneumonia. Forty-five of the 66 cases with diminished breathing at first examination and 44 of the 74 cases with bronchial breathing were eventually diagnosed as collapse. Physical examination, therefore, except when it shows definite mediastinal displacement, is of little value in separating pneumonia from collapse. The important point to remember is that bronchial breathing may indicate either pneumonic consolidation or an atelectatic area with open bronchus. (In interpreting physical signs, it should be borne in mind that an elevation of one side of the diaphragm, which frequently follows abdominal operation, will often account for diminished breathing at the base without the presence of atelectasis.)

Table I shows the large number of cases of bronchitis in which the X-ray has shown no parenchymal involvement. Many of these cases ran the same clinical course as those in which portions of the lung were involved. We believe, therefore, that a purulent bronchitis develops in a large percentage of postoperative cases; that in some cases the infection is limited to the bronchi; and that in the intermediate group of pulmonary complications, now under discussion, there is an accompanying "pneumonitis," combined at times with atelectasis due to occlusion of the bronchi by exudate. We have found no evidence that atelectasis necessarily precedes pneumonitis and have been able to prove atelectasis in only 47 per cent of our series of cases. In most instances a sharp distinction cannot be drawn between pneumonitis and collapse in this intermediate group, the underlying lesion in all cases being purulent bronchitis. (An occasional instance has been observed with "simple collapse," having very little fever and no expectoration.)

As noted in the beginning, there is a small group of typical bronchopneumonias which can be clearly differentiated from the intermediate group just described. In 1930 and 1931, there were 30 cases of this type. Eleven of the 13 fatal cases were included in this group and showed, from the start, a diffuse bronchopneumonic process in the upper as well as the lower lobes and there was no evidence that there had been a preceding atelectasis. In the 2 other fatal cases, pneumonia may have developed in an atelectatic area.

Since this is primarily a statistical study, the theories of etiology will not be further discussed, nor will the considerable literature on the subject be reviewed, both having been frequently and exhaustively presented by other authors.

TABLE II.—MORBIDITY AND MORTALITY

	Percentages		
	1929	1930	1931
"Pneumonia" and collapse			
In all operations	3.7	6.8	5.2
Laparotomies and herniorrhaphies only	7.7	14.3	11.3
Mortality due primarily to "pneumonia" and collapse			
In all operations	0.3	0.6	0.4
Laparotomies and herniorrhaphies only	0.9	1.1	0.8
In "pneumonia" and collapse	9.9	8.7	8.6
Mortality, all causes			
In "pneumonia" and collapse	33.3	24.3	20.3

Percentage of complications. Table II gives a summary of the percentage of complications with the accompanying mortality incidence occurring on the General Surgical Services[1] in the 3 years, 1929, 1930, and 1931. Although the author's routine personal observation of patients did not begin until 1930, a very careful study of every surgical record, in 1929, gives statistics that are of interest for comparison. The figure for incidence of postoperative pulmonary complications following general and abdominal operations is higher than that reported by other authors (1, 3, 6).

Mortality. In the group in which death was "due primarily to pneumonia and collapse" are included those patients whose postopera-

[1]In the Massachusetts General Hospital there are special services for genito-urinary, orthopedic, eye, ear, nose, and throat surgery.

TABLE III.—MORTALITY

Complication considered as	Number of patients 1930	1931
Primary cause of death	5	8
Major contributing cause of death	16	8
Minor contributing cause of death	25	14
No connection with death	12	8
Total	58	38

TABLE IV.—SEVERITY

	Number of patients 1930	1931
Severe	35	17
Moderate	140	122
Mild	64	48
Total	239	187

tive pulmonary complication was either a primary or a major contributing cause of death. It will be noted that although a rather large percentage of patients developing pulmonary complications do not live, the percentage of those in whom the complication can be considered as a definite factor in the patient's death is comparatively small. The fact is again emphasized in Table III, which analyzes further the group who have had pulmonary complications and have died.

Severity. Table IV presents the cases grouped according to severity. The cases presenting clinical symptoms and signs of bronchitis, but in which the X-ray demonstrated definite parenchymal involvement, have been classified as "mild."

Sex and type of operation. The most important factors in the occurrence of postoperative pulmonary complications are type of operation and sex of the patient. The figures for the various types of operation in the two sexes are given in Tables V and VI. These figures bring out the following facts. The incidence of pulmonary complications among men is at least twice that among women. Complications are more than twelve times as frequent following laparotomy and herniorrhaphy as after operations in the non-abdominal group. They occur most frequently following operations on the stomach and duodenum, gall bladder, and intestines. Therefore, the group of men having operations on the stomach and duodenum, gall bladder, and intestines has been designated as the "bad risk" group, because of their consistently high percentage of pulmonary complications. In the group of non-abdominal operations, complications have occurred most frequently after operations on the thyroid. Of 134 patients having thyroid operations in 1930, 10 developed pulmonary complications, which gives a percentage of 7.5; and in 1931, 7 of 102 patients, or 6.9 per cent, developed complications. It will be noted that of the fourteen complications following non-abdominal operations in 1931, half occurred after operations on the thyroid.

Sepsis and perforation. Table VII gives a further analysis of the cases grouped in Tables V and VI under "stomach and duodenum" and "appendix." The extraordinarily high

TABLE V.—TYPE OF OPERATION AND SEX—1930

Operation on	Total			Male			Female		
	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications
Stomach and duodenum	107	41	38.3	85	37	43.5	22	4	18.1
Intestines	124	30	24.2	75	23	30.7	49	7	14.2
Gall bladder	158	38	24.1	43	17	39.5	115	21	18.2
Appendix	472	54	11.4	244	36	14.7	228	18	7.8
Miscellaneous laparotomy	120	13	10.8	69	9	13.0	51	4	7.8
Gynecological laparotomy	265	13	4.9	—	—	—	265	13	4.9
Hernia	260	26	10.0	223	23	10.3	37	3	8.1
Total abdominal and hernias	1506	215	14.3	739	145	19.5	767	70	9.1
All others	1963	24	1.2	1030	16	1.5	933	8	0.8
Total	3469	239	6.8	1769	161	9.1	1700	78	4.5

TABLE VI.—TYPE OF OPERATION AND SEX—1931

Operation on	Total			Male			Female		
	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications
Stomach and duodenum	97	41	42.3	73	37	50.7	24	4	16.7
Intestines	121	21	17.4	74	16	21.6	47	5	10.6
Gall bladder	172	24	14.0	30	9	30.0	142	15	10.6
Appendix	488	44	9.0	249	35	14.1	239	9	3.8
Miscellaneous laparotomy	128	7	5.5	74	6	8.1	54	1	1.9
Gynecological laparotomy	312	23	7.4	—	—	—	312	23	7.4
Hernia	213	13	6.1	182	13	7.1	31	—	—
Total abdominal and hernias	1531	173	11.3	682	116	17.0	849	57	6.7
All others	2065	14	0.7	1162	7	0.6	903	7	0.8
Total	3596	187	5.2	1844	123	6.7	1752	64	3.7

TABLE VII.—COMPARATIVE STATISTICS IN RELATION TO SEPSIS

Operation	1930						1931					
	Male			Female			Male			Female		
	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications
Gastrostomy	15	8	53.3	4	—	—	11	3	27.3	9	2	22.2
Gastro-enterostomy	25	8	32.0	9	3	33.3	30	14	46.7	9	1	11.1
Gastric resection	19	7	36.8	8	1	12.5	17	10	58.8	4	1	25.0
Gastric and duodenal suture	19	12	63.2	1	—	—	13	9	69.2	1	—	—
Cholecystgastrostomy	7	2	28.6	—	—	—	2	1	50.0	1	—	—
Intestinal, palliative	52	13	25.0	36	6	16.7	47	12	25.5	33	2	6.1
Intestinal resection	18	8	44.4	13	1	7.7	23	2	8.7	10	3	30.0
Intestinal anastomosis	3	—	—	—	—	—	2	1	50.0	3	—	—
Intestinal suture	2	2	100.0	—	—	—	2	1	50.0	1	—	—
Appendectomy alone	127	9	7.1	101	6	5.9	131	13	9.9	114	3	2.6
Appendectomy with exploration	43	8	18.6	87	5	5.7	45	5	11.1	97	2	2.1
Appendectomy with drainage	68	19	27.9	33	5	15.2	62	15	24.2	24	3	12.5
Incision and drainage appendix abscess	6	—	—	7	2	28.6	11	2	18.2	4	1	25.0

percentage of pulmonary complications in men following gastric and duodenal *suture* is of especial interest, as well as the high percentage of complications occurring in 1930 after gastrostomy alone. That complications do not occur simply as a result of opening the abdomen, but are dependent to a great extent upon the pre-operative condition of the individual patient is well brought out by the analysis of the appendectomy group. The figures show a much higher percentage of pulmonary complications following appendectomy with drainage than after simple appendectomy or appendectomy with exploration.

Pre-operative respiratory infection. The tables so far mentioned stress the importance of the type of operation and the presence of pre-operative sepsis. In addition, the relation of pre-existing respiratory infection to the development of postoperative pulmonary complications has been of interest. Of the 239 complications occurring in 1930, only 26 (10.8

TABLE VIII.—LAPAROTOMIES AND HERNIA OPERATIONS—MONTHLY INCIDENCE

	Per cent postoperative pneumonia and collapse	
	1930	1931
January	7.9	16.4
February	12.7	13.6
March	14.4	14.3
April	21.1	7.1
May	16.7	12.8
June	9.7	9.2
July	10.8	9.2
August	13.7	9.9
September	13.3	10.3
October	16.4	11.8
November	19.8	13.4
December	17.0	8.7
Percentage for year	14.3	11.3

per cent) had pre-operative respiratory infection of an acute or chronic nature. Of the 187 cases in 1931, 35 patients (18.7 per cent) had such pre-operative infection. The apparent increase in the 1931 figures is undoubtedly due to the careful recording of pre-operative infections by the nurse in charge of carbon dioxide inhalations.

There are no figures available to show the relation of acute respiratory infection in the community at large to the occurrence of postoperative pulmonary complications in the hospital except those for lobar pneumonia, which show that the pneumonia curve is not paralleled by our curve for pulmonary complications.

Monthly incidence. Table VIII and Figure 1 give the percentage of postoperative pulmonary complications by months for the 2 years, 1930 and 1931. Since the incidence of pulmonary complications is so much higher after laparotomy and herniorrhaphy, the monthly incidence is computed for this type rather than for the total number of operations. In 1930, there was a definitely higher percentage of complications in the late spring and late fall than during the summer, but there is not the marked seasonal variation which has been reported by some authors. In 1931, the highest percentage occurs in January, February, and March, with slight elevation again in October and November. Improved methods of bronchial drainage are probably responsible for the lower percentages in the latter part of 1931.

The severity of the complication in relation to season has been studied, and here, the figures for the 2 years differ markedly. The severe complications in 1930 occurred predominantly in October, November, December, and March—in the winter months. In 1931, almost half of the severe complications occurred in the 4 months, May to August, inclusive — predominantly in the summer months.

Anæsthesia. Table IX shows the percentage of pulmonary complications occurring after laparotomies and herniorrhaphies under the different types of anæsthesia. The figures for 1931 do not include the total operations for the year since they are compiled from a group of cases selected for a special study (4). However, they do cover a great majority of the operations performed and are a representative group for the year. (The patients given spinal or rectal anæsthesia with supplementary ether are included in the "inhalation" group.)

The high percentage of complications occurring in the group which were given spinal anæsthesia is of interest, and many surgeons have been of the opinion that this high percentage was due to the fact that the poorer operative risks were selected for spinal anæsthesia. Consequently, an attempt was made to analyze a type of operation in which the pre-operative condition of the patients in the group given ether was as nearly as possible the same as the pre-operative condition of the patients in the group given spinal anæsthesia. The male patients with hernias, between the ages of 20 and 60 years, operated upon in 1930, were selected as more nearly approximating these requirements than any other group. Table X gives the results and shows a higher percentage of complications after spinal anæsthesia in every age group. It is true, however, that a further study of the group revealed that of the 66 cases selected for inhalation anæsthesia, all were considered "good ether risks" except 8 who were designated as "fair." (Two of these patients had strangulated hernias.) Of the 54 patients selected for spinal anæsthesia, 19 were listed as "fair ether risks" and 3 as "poor" risks. (Four patients were operated on for strangulated hernias.) It would seem from this that the increased percentage of complications after spinal anæsthesia is due

TABLE IX.—ANÆSTHESIA

	Incidence in laparotomies and hernia operations					
	1930			1931—CO_2 study		
	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications
Inhalation	1198	158	13.1	1012	123	12.2
Spinal	227	42	18.5	195	28	14.4
Avertin	—	—	—	35	3	8.6
Local	79	15	18.9	73	13	17.8

TABLE X.—MALE PATIENTS WITH HERNIAS—1930

Age	Anæsthesia					
	Inhalation			Spinal		
	Operations	Complications	Per cent complications	Operations	Complications	Per cent complications
20 to 29 years	25	2	8.0	6	1	16.6
30 to 39 years	13	2	15.3	7	2	28.5
40 to 49 years	18	3	16.7	17	4	23.5
50 to 59 years	10	1	10.0	24	4	16.6
Total	66	8	12.1	54	11	20.3

in part to a poorer pre-operative condition of the patient.

It is of especial interest to note that in both years the percentage of complications was highest after local anæsthesia. Most of the operations in this group were palliative intestinal operations done for relief of intestinal obstruction, due to malignancy. This lends further support to the opinion that the pre-operative condition of the patient is a more definite factor in the development of pulmonary complications than length of operation or type of anæsthesia.

The group of patients given avertin in 1931 is a small series of carefully selected "good risks."

Bacteriology. In the winter of 1930, a pneumococcus typing was done on the sputa of 44 patients. Of this number, the specimens from 14 patients contained very few pneumococci and of the 30 sputa which gave a good growth of pneumococci in the mouse, 10 were Type III and the remainder Type IV. At the present time a more complete study of the bacteriology of postoperative pulmonary complications is being made at the Massachusetts General Hospital.

SUMMARY

Statistics based upon 2 years' personal observation of the postoperative pulmonary complications occurring on the General Surgical Services of the Massachusetts General Hospital have been presented. Figures have been tabulated separately for the 2 years showing strikingly similar percentages in most instances.

A brief summary combining the figures for the 2 years brings out the following points:

1. Purulent bronchitis develops in a large percentage of patients after operation. In the type of pulmonary complication discussed, bronchitis is associated with "pneumonitis." In 47 per cent of the cases there has been sufficient bronchial obstruction to give rise to atelectasis.

2. Eleven of the 13 fatal cases were true bronchopneumonias, without evidence of preceding atelectasis.

3. Pneumonia, "pneumonitis," or collapse has developed in 6.0 per cent of all operations and in 14.0 per cent of laparotomies and herniorrhaphies, and in 7.2 per cent of thyroid operations.

4. The pulmonary complication is regarded as primarily responsible for, or as a major contributing cause of death in 0.5 per cent of the total operations performed and in 1.2 per cent of the laparotomies and hernia operations.

5. In practically any given type of operation, the percentage of complications is at least twice as high for men as for women.

6. Among males, the incidence of complications following operations on the stomach and duodenum is 46.8 per cent; on the gall bladder, 35.6 per cent; and on the intestines, 26.2 per cent. This group is designated as the "bad risk" group.

7. Following gastrostomies and palliative operations for intestinal obstruction, 22.2 per cent of the patients developed pulmonary complications; and among the patients having gastric and duodenal suture, the incidence was 61.8 per cent.

8. After drained appendices, 22.5 per cent complications occurred, as compared with 6.6 per cent following simple appendectomy.

9. Of the 426 complications, only 14.3 per cent had pre-operative, acute, or chronic respiratory infection.

10. The seasonal curve does not parallel that for lobar pneumonia or show any consistent seasonal rise.

11. The somewhat lower percentage in 1931 is probably due to better bronchial drainage.

12. In laparotomies and herniorrhaphies, 12.7 per cent of the patients operated upon under inhalation anæsthesia developed pulmonary complications; 16.6 per cent of those under spinal anæsthesia; and 18.4 per cent of those under local anæsthesia.

CONCLUSIONS

1. Purulent bronchitis and "pneumonitis" are present in practically all instances of the type of pulmonary complication here described. Atelectasis is associated with the infection in about one-half the cases, but severe and fatal cases are usually true bronchopneumonias without evidence of atelectasis at any stage.

2. Complications occur especially in males following operations on the stomach, and duodenum, gall bladder, and intestines.

3. Pre-operative sepsis and perforation, as well as malignancy and poor general condition, are important factors.

4. Season and pre-operative respiratory infection play a minor part.

5. From the statistical standpoint, the type of anæsthesia is without significance.

We wish to express our grateful appreciation to the entire Surgical Service and the X-ray Department for their interest and ever ready co-operation.

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TWO RAPID TESTS FOR PREGNANCY

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SINCE it has been shown that the rhythmic vascular changes in endometrial transplants onto the iris are arrested by follicular hormone (Markee, 1929), the possibility of using that modification of the uterine vascular rhythm as a test for the presence of follicular hormone in the urine of pregnant women suggested itself. Two tests for pregnancy have been devised and their advantages and inherent difficulties investigated. The tests were made in two ways: directly by the injection of follicular hormone that had been extracted from the urine; and indirectly by the intravenous injection of untreated urine from pregnant women. The urine of 147 pregnant and 26 non-pregnant women has been tested.

METHOD OF RECORDING THE RHYTHMIC UTERINE VASCULAR CHANGES

It was found that endometrial transplants in the anterior chamber of the eye rhythmically blush and blanch (Markee, 1929). Kymographic records of these color changes were made in the following way. Six lines, equal distances apart, were drawn around the drum of a kymograph to represent the colors of 0, 10, 20, 30, 40, and 50 per cent of hæmoglobin, respectively. The color changes, in the transplant, were recorded by comparing the color of the transplant with the colors on a Tallqvist hæmoglobinometer and turning the recording dial to the appropriate percentages. The fluctuations in the color of the transplants could thus be graphically recorded.

THE MODIFICATION INDUCED BY FOLLICULAR HORMONE

When 20 rat units, per kilogram, of follicular hormone are injected into a rabbit, the following modification of the uterine vascular rhythm occurs. Within 10 minutes the color of the transplant is noticeably intensified and within 15 minutes the transplant becomes 20 per cent redder. In 20 minutes a slight irregularity of the cycle develops and the ratio of the time in vasoconstriction to that in vasodilation is greater than 1:6. Thirty minutes after the injection of follicular hormone the ratio is 1:10 or greater. These modifications in the vascular cycle continue until 40 minutes after the injection, when the rhythmic vascular changes cease and the color of the transplant is comparable to that of 50 per cent hæmoglobin.

The injection of follicular hormone that has been extracted from the urine of pregnant women also arrests the rhythmic vascular changes in vasodilation. The method of extracting the follicular hormone from the urine is only slightly different from the one described by Frank and Goldberger (1930) and consists of shaking 150 cubic centimeters of urine with 100 cubic centimeters of ether, in a separatory funnel, for 30 minutes, drawing off the ether and repeating the extraction with a second sample of ether. The two samples of ether are combined and evaporated to dryness at room temperature, under reduced pressure. The residue is dissolved in olive oil and injected subcutaneously. Since the extraction of the follicular hormone by this method requires only 1 hour and 20 minutes and the modification of the vascular rhythm occurs 40 minutes after the injection of the extract, the test may be completed in 2 hours.

Since the rhythmic vascular changes in endometrial transplants onto the iris are arrested by the presence of large amounts of follicular hormone in the blood stream, they are arrested either when follicular hormone is injected or when it enters the blood stream from the rabbit's own ovaries (Markee, 1929). The vascular rhythm in the endometrial transplants onto the iris is therefore arrested in vasodilation 7 to 8½ hours after mating or the intravenous injection of urine from pregnant women. The modification of the vascular rhythm, which occurs at that time, is similar in every respect to the modification that follows the injection of follicular hormone.

[1] Aided by a grant from the National Research Council Committee on Research in Problems of Sex.

THE DIRECT METHOD OF TESTING FOR PREGNANCY

The direct test has a number of advantages over the indirect one. Either gonadectomized or non-gonadectomized males or females may be used. The possibility exists that the non-ovariectomized rabbit may at times produce a sufficient amount of follicular hormone to cause a modification of the vascular rhythm in the endometrial transplants, but this is remote because the rabbit apparently does not ovulate spontaneously. Since a kymographic record is made of the uterine vascular changes immediately before the extract is injected, this possible source of error is eliminated. The main advantage of the direct over the indirect test is that the diagnosis can be made 40 minutes after the injection or 2 hours after the specimen of urine has been obtained. Only a limited number of animals are required since the same rabbit may safely be used every third day. A correct diagnosis of pregnancy by both the direct and indirect methods was made as early as the forty-seventh day after the beginning of the last menstrual flow.

Mazer (1929) states that although follicular hormone is not present in the blood in increased concentration during the first 8 weeks of pregnancy it is present in the urine during that period. He suggests that the reason for its elimination through the kidneys may be that it is injurious to the conceptus during the early stages of development. This hypothesis is supported by Kelley's (1931) finding that, in the guinea pig, the injection of follicular hormone during the first 4 weeks of pregnancy causes abortion. Bland (1932) found that the Mazer test for pregnancy (based on an increase in the amount of follicular hormone in the urine) was as reliable as the Aschheim-Zondek test. Therefore, it would seem reasonable to suppose that a reliable diagnosis may be made as early in pregnancy by the direct method as by the Aschheim-Zondek method.

THE INDIRECT METHOD OF TESTING FOR PREGNANCY

Only non-ovariectomized females can be used in the indirect test. Since the intravenous injection of urine from pregnant women induces pseudo-pregnancy, the animals should not be used oftener than every third week. The diagnosis can not be made until 7 to 8½ hours after the injection of the urine. These unavoidable disadvantages in the use of the indirect test are compensated for by the fact that it is more easily made since untreated urine is injected. Since a record is made of the vascular changes in the endometrial transplants immediately before the urine is injected, it is definitely known whether or not the animal may safely be used. It is, of course, possible that ovulation might be initiated by the handling of the animal at the time that the injection is made. However, since no one who has used the Friedman test for pregnancy has reported such an occurrence, this does not seem to be a serious or a probable source of error.

The Cohnheim method of transplantation into the eye (1877) is not a difficult one and the time spent preparing the animals is not important since the same animal is used repeatedly. A further saving of time is effected since it is not necessary to perform an exploratory operation either to determine whether the animal will be a reliable indicator or to make the diagnosis.

The greatest difficulty encountered in the use of these tests for pregnancy is inherent in both methods. As previously reported (Markee, 1932), the vascular changes observed in endometrial transplants in the anterior chamber of the eye are of two kinds; the rhythmic changes and those that follow fright. The former are arrested in vasodilation by follicular hormone but the latter are not. However follicular hormone causes a decrease in the intensity of the vasoconstrictions that follow fright. Hence the diagnosis is more reliably made, if the animal is observed under conditions that eliminate fright. To this end it is placed in a small box, three sides of which are tall enough so that it can not see over them. Since the presence of the observer seems to excite a rabbit, especially if he stares into its eye, the best results are obtained by using a microscope that magnifies three times and has a focal length of about 20 inches.

In rabbits without an increased amount of follicular hormone, a vasoconstriction is induced only when the animals are frightened

during the middle third of a vascular cycle. However, if the vascular cycles have been lengthened or arrested by the injection of follicular hormone, fright may induce a vasoconstriction in one of two transplants in one eye and not in the other.

Because of these facts, it is sometimes difficult to decide whether the vasoconstrictions observed are induced by fright or not. It has, therefore, been necessary to devise some method by which the observer may distinguish between the vasoconstrictions induced by fright and the spontaneous rhythmic vascular changes. The two kinds of vascular changes may easily be distinguished because a vasoconstriction occurs in the blood vessels of the ears 17 seconds after a rabbit is frightened. Hence, vasoconstrictions that occur in the endometrial transplants at about the same time as the vasoconstrictions in the ear are fright vasoconstrictions and those that occur in the transplant alone are rhythmic vascular changes. During pregnancy tests the fright vasoconstrictions are ignored, since they are not rhythmic vascular changes and are not completely inhibited by follicular hormone.

Specimens of urine from 147 pregnant and 26 non-pregnant women were tested by both the direct and indirect methods and all of the diagnoses have agreed with the clinical histories. Veler and Doisy (1928) have shown that the amount of follicular hormone in the urine of pregnant women increases as pregnancy progresses. We have found that enough follicular hormone to effect the modification of the uterine vascular rhythm can be extracted from smaller amounts of urine as pregnancy progresses. However, since we have not used 24 hour samples, it has not been possible to compare our results with theirs nor to discover how small an amount of urine from a woman in the later months of pregnancy will evoke the reaction.

Both the direct and indirect tests for pregnancy are based on the modification of the vascular rhythm in endometrial transplants by the presence of relatively large amounts of follicular hormone in the blood stream of the test animals. The direct test is made by injecting the follicular hormone that has been extracted from 150 cubic centimeters of urine. That volume of urine has been used in all tests because it was not possible to extract enough follicular hormone from 150 cubic centimeters of urine from non-pregnant women to arrest the rhythmic vascular changes in the endometrial transplants and because 150 cubic centimeters of urine from pregnant women yields enough follicular hormone to arrest the vascular rhythm.

In all probability, only part of the follicular hormone in the urine was extracted by the method that was used. However, the efficiency of the method of extraction determines only the amount of urine that is used, since, if a high percentage of follicular hormone were obtained, less urine would be required to yield enough follicular hormone to arrest the rhythmic vascular changes in the endometrial transplants.

Although all the diagnoses made by the direct method have agreed with the clinical histories, it should be pointed out that if for any reason large amounts of follicular hormone should be present in the urine of non-pregnant women, the rhythmic vascular changes would be arrested in vasodilation and so a false diagnosis of pregnancy would be made. This method is merely a test for the presence of increased amounts of follicular hormone in the urine and is only indirectly a test for pregnancy. It should also be pointed out that it is not definitely known just how soon after conception there is a marked increase in the amount of follicular hormone in the urine. Therefore, only experience will determine whether or not this method will reliably test for early pregnancy.

A considerable amount of time is spent extracting the follicular hormone from the urine since, if it is not done by hand, the mixture of urine and ether will become foamy. This will sometimes happen no matter how carefully the extraction is made. For these reasons, the direct test may prove to be less satisfactory than the indirect one even though the diagnosis of pregnancy may be made 2 hours after the specimen has been obtained.

Although these two methods of arresting the rhythmic vascular changes in the endometrial transplants have so far been used only as tests for pregnancy, the direct method

might be used as a test for increased elimination of follicular hormone through the kidneys or for the presence of increased amounts of follicular hormone in the blood. The indirect method might be used as a test for increased amounts of hypophyseal hormone either in the urine or in the blood.

SUMMARY

1. The modification of the rhythmic vascular changes in endometrial transplants onto the iris that is induced by the injection of follicular hormone, extracted from the urine from pregnant women, can be used as a test for pregnancy. The diagnosis of pregnancy can be made 2 hours after the specimen of urine has been obtained.

2. The intravenous injection of urine from pregnant women causes an increased production of follicular hormone and indirectly induces a modification of the uterine vascular rhythm in the endometrial transplants. By means of this indirect test the diagnosis of pregnancy can be made 8½ hours after the urine has been injected.

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THE COMPARATIVE BACTERICIDAL ACTION OF MERCUROCHROME AND IODINE SOLUTIONS USED AS LOCAL TISSUE DISINFECTANTS[1]

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IT IS the purpose of this paper to present experimental data concerning the relative bactericidal value of such mercurochrome and iodine solutions as are commonly used locally for the purpose of sterilizing the unbroken skin, oral mucous membranes, abrasions, and both superficial and deep wounds.

The present report deals with the continuation of a study of local tissue antiseptics which was begun several years ago at the request of the Medical Supply Division of the Office of The Surgeon General, U. S. Army. One of the original aims of the investigation was to answer a hypothetical procurement question as to whether some locally produced tissue disinfectant might not be found suitable to replace tincture of iodine, if, for any reason, it should become difficult for the Army to obtain iodine from the usual foreign sources. Mercurochrome-220 soluble was selected as one of the substances to be studied, mainly because of its popular use as a general antiseptic and because of certain enthusiastic claims made concerning its supposed germicidal value.

In the earlier work with mercurochrome, the author (10) determined its germicidal action on several representative species of pathogenic bacteria which might be encountered as contaminants on the unbroken skin; while Rodriguez (6) studied its effect on the normal bacterial flora of the oral mucous membranes. The results of these two investigations, which were published simultaneously in 1928, may be briefly summarized as follows: In the author's work three types of mercurochrome solutions were used (2 per cent aqueous, 2 per cent alcohol-acetone-aqueous, and 5 per cent alcoholic), also two solutions of iodine (the U. S. P. tincture, 7 per cent and half strength tincture 3.5 per cent), for different time intervals on living skin contaminated with a variety of pathogenic organisms including: Staphylococcus aureus, Streptococcus pyogenes. Streptococcus scarlatinae, Escherichia coli, Clostridium welchii and Bacillus anthracis, respectively. Bactericidal action was estimated by preparing from each area of treated skin, a series of carefully controlled cultures to determine whether the specific test organisms had been killed. From this work it was shown that, while the mercurochrome solutions had some antibacterial action *in vitro* against the non-sporogenous organisms, they were ineffectual even under these conditions against the spores of Clostridium welchii; and that regardless of the type of organism its action was relatively weaker than that of tincture of iodine. The relative ineffectiveness of mercurochrome was emphasized still more strikingly by the results of the experiments in skin disinfection. In some instances, the 5 per cent alcoholic solution of mercurochrome caused a reduction in the number of bacteria, but in 45 of 46 tests it failed to sterilize the skin; the 2 per cent acetone-alcohol-aqueous solution also caused some numerical reduction of the organisms in certain tests, but it, too, failed in 45 of 50 tests; while the 2 per cent aqueous mercurochrome solution failed to sterilize the skin in 55 of 56 tests. Considering these results as a whole, it is apparent that mercurochrome sterilized the skin in only 7, or 4.8 per cent, of 145 tests, and that it failed in 95.2 per cent. In contrast to these results the half strength tincture of iodine caused a reduction in viable organisms in 20 of 42 tests and sterilized the skin in the other 22 tests. The U. S. P. tincture of iodine failed only 7 times—in 2 tests with staphylococcus and in 5 tests with Clostridium welchii spores—and in these 7 tests the numbers of viable organisms were reduced. Tincture of iodine was found to be effectively bactericidal in 51, or 87 per cent, of the 58 tests. These carefully controlled experiments, which showed that the mercurochrome solutions used were relatively too ineffectual to be of practical value for the destruction of the 6 species of pathogenic bacteria present as con-

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taminants on living skin led to the conclusion that mercurochrome was not suitable for use as a substitute for tincture of iodine in preoperative skin disinfection.

Unfavorable results were also obtained with mercurochrome by Rodriguez in his experimental investigation of this drug as a preoperative disinfectant for use on the oral mucous membranes. His conclusions were as follows: "Mercurochrome-220 soluble (2 per cent aqueous solution) is too feeble an antiseptic to be used safely as a surface disinfectant of the oral mucous membranes. The 5 per cent mercurochrome solution in alcohol and the mercurochrome-alcohol-acetone preparations possess decided advantages over the aqueous solution, but fail in too large a proportion of cases to be considered effective in surface disinfection of the oral mucous membranes. Iodine in 3.5 per cent and even in 1.75 per cent strength, preferably in glycerin, is an effective germicide from the standpoint of surface disinfection of the oral mucous membranes."

These observations have since been confirmed by other workers, although there was some disagreement on the part of Reddish and Drake and later by Scott, Hill and Ellis (9). The former, in an article which appeared simultaneously with those by Rogriguez and the author, published experiments in which, by a different technique, mercurochrome and iodine were tested for disinfectant action on rabbit skin contaminated with a strain of Staphylococcus aureus. In this paper Reddish and Drake (5) claimed that "2 per cent mercurochrome in aqueous-alcohol-acetone solution and tincture of iodine are equally effective in disinfecting the unbroken skin"; but it appears that their conclusions were not warranted by their published results, even with the one species of bacteria considered. Moreover, these writers failed to support their broad conclusions by tests with the other important pathogenic skin contaminants. Also no mention was made of the fact that one of them (Reddish, 4) had previously stated in official individual reports from his laboratory in the Department of Agriculture, copies of which were furnished me, that, even *in vitro*, mercurochrome was ineffective against such spore forming bacteria as Clostridium welchii and Clostridium tetani. In one of these official reports made in 1925, Reddish stated that: "Clostridium tetani is not killed by 5 per cent aqueous or 5 per cent alcoholic mercurochrome in 2 hours. Tincture of iodine kills it sometime between 30 minutes and 1 hour, but close to 30 minutes because it shows a ∓ at 30 minutes." In another such report he showed that 5 per cent alcoholic mercurochrome failed to kill the Welch bacillus, *in vitro*, in 2 hours, while "Clostridium welchii is practically killed after 15 minutes exposure to tincture of iodine. . . . and certainly entirely all killed by 30 minutes' exposure." The following remark was added: "*Tincture of iodine is decidedly better than 5 per cent alcoholic mercurochrome against Clostridium welchii, the commonest of the war wound anaerobes.*" The obvious discrepancies between these observations made by Reddish in 1925 and the conclusions published by Reddish and Drake in 1928, without any mention of Clostridium welchii or Clostridium tetani, appear to detract considerably from the value of their statements on skin disinfection.

Delafield in reviewing these publications (5, 6, 10) commented as follows on the report by Reddish and Drake: "Adopting a somewhat different technique to that used by J. S. Simmons (*supra*), conclusions are reached which are at variance with those of the latter investigator. Only one test organism was used—Staphylococcus aureus 209—and the bacteriological method was different. The 2 per cent alcohol-acetone-aqueous solution of mercurochrome is said to be as effective as tincture of iodine, and, because of the well known objections to the latter, to be far more suitable for skin disinfection. (The tabular statement of results does not appear to justify this sanguine view of the efficacy of mercurochrome.)"

Sinclair, in a report to The Surgeon General, U. S. Army, dealing with his experimental studies of tissue disinfectants, made the following statement concerning mercurochrome: "In support of previous complete report by Major James S. Simmons and to controvert the editorial (2) criticism of his technique in the *Journal of the American Medical Association*, September 8, 1928, a test was made, the

technique of Dr. G. F. Reddish being used. Methods and results are included in Protocol I, enclosed. This experiment supports the previous report of Major Simmons that mercurochrome is not an effective substitute for iodine in skin disinfection. Although these results were obtained after strictly following the technique of Reddish (4), they are strangely diametrically opposite to results obtained by him. However, they agree very closely with those obtained by Simmons," from which he drew the following conclusion: "From the standpoint of bactericidal action, tincture of iodine is far superior to any of the solutions used (mercurochrome) on unbroken skin for disinfection purposes."

In 1929, Scott, Hill, and Ellis (9) published an article in defense of the 2 per cent aqueous-alcohol-acetone solution of mercurochrome, which had been presented as a pre-operative skin disinfectant in 1925, by Scott and Hill (8) who had made the claim that "better skin sterilization is obtained with it than with iodine." While the more recent article dealt mainly with controversial matter, it also included the results of disinfection tests with: (a) unwashed human skin, the bacterial contamination of which was necessarily variable as to quantity and species; and (b) with disinfection of shaven rabbit skin contaminated by applications of 24 hour broth cultures of Staphylococcus aureus-209. It will be noted that the latter method of preparing the skin contamination is essentially similar to that outlined in their original report in which they stated that the shaven rabbit skin was "heavily inoculated" by smearing it with 18 hour 1 per cent dextrose broth cultures. This point is emphasized only because of the marked disagreement between the results reported by Scott and Hill in 1925 and those by Scott, Hill and Ellis in 1929. In the earlier article, the tabular results indicated that within 2, 1½, or even 1 minute's time, the 2 per cent mercurochrome solution caused complete sterilization of skin contaminated with such heavy inoculations of Staphylococcus aureus in all of 25 tests. However, according to the 1929 report, the same type of mercurochrome solution applied for 5 or more minutes to rabbit skin similarly contaminated with 24 hour broth cultures of Staphylococcus failed to sterilize the skin, and the cultures showed "heavy growth of Staphylococcus aureus in 100 per cent of the 12 tests." In 9 parallel skin tests with tincture of iodine, the cultures also showed "heavy growth" and 2 were recorded as sterile. In the later article the authors concluded that the two drugs were equally effective in sterilizing the uncleansed human skin; but no explanation was offered for the modification of their earlier claim concerning the supposed superiority of mercurochrome, or for the discrepancies in their various published results. These claims by Scott, Hill and Ellis, which agree in substance with those of Reddish and Drake, are subject to similar objections and, obviously, cannot be accepted on the experimental evidence offered.

In 1931, Scott and Birkhaug (7) reported the results of an investigation made to determine the relative bactericidal value of certain skin disinfectants, including: (a) metaphen (0.5 per cent in alcohol-acetone solution; (b) tincture of iodine (7 per cent); and (c) mercurochrome (2 per cent in alcohol-acetone solution). Each solution was used in 104 three minute tests, including both surface and deep disinfection tests on unwashed human skin; and in 125 three minute tests with rabbit skin contaminated with undiluted 18 hour broth cultures of Staphylococcus aureus, Streptococcus hæmolyticus, Bacillus coli and Bacillus subtilis (spores), respectively. The results were determined by a technique somewhat similar to that used in my investigations mentioned above. After 3 minutes' treatment of the skin, cultures were made with two moistened cotton swabs which were first rubbed vigorously against the center of the treated area and then immersed in 100 cubic centimeters of Douglas' broth contained in a 250 cubic centimeter Erlenmeyer flask. After incubation for 48 hours at 37 degrees C, the results of skin sterilization were determined according to the growth of bacteria in the test cultures. Their results were as follows: In the surface tests with rabbit skin heavily contaminated with undiluted 18 hour broth cultures of Staphylococcus aureus, Streptococcus hæmolyticus, Bacillus coli and the spore-bearing Bacillus subtilis, metaphen killed the organisms in 89.7 per cent, tincture of iodine

Fig. 1. From Report to The Surgeon General, U. S. Army, by Major Charles G. Sinclair, M.C., Department of Bacteriology, Army Medical School, Washington, D. C., September, 1928.

in 79.7 per cent, and mercurochrome in 51.5 per cent of the tests. The results in the deep sterilization tests on rabbit skin contaminated with the same species of bacteria were as follows: metaphen 87 per cent, tincture of iodine 47 per cent, and mercurochrome 26 per cent. In the disinfection tests on the surface of normal human skin, metaphen was effective in 98 per cent, tincture of iodine 96.1 per cent, and mercurochrome in 28.8 per cent of 52 tests each. In the deep tests on human skin, epithelial scrapings being used, metaphen produced sterility in 94.2 per cent, tincture of iodine in 84.6 per cent, and mercurochrome in 3.8 per cent of 52 tests each. Although no experiments were reported with Clostridium welchii or Clostridium tetani, this investigation by Scott and Birkhaug again confirms the earlier conclusions of Simmons, Sinclair and others, concerning the relative ineffectiveness of mercurochrome as a skin disinfectant.

More recently, Kelser and Mohri have reported the results of experiments from which they concluded that "the commonly marketed 2 per cent solution of mercurochrome-220 soluble, is not a satisfactory skin disinfectant for use in veterinary practice. Compared with tincture of iodine (U.S.P.) for such purpose, the latter proved superior. A concentration of 1 part of tincture of iodine (U.S.P.) in 10 parts of a suspension of tetanus spores killed the spores within 10 minutes. A similar concentration of mercurochrome (2 per cent aqueous) failed in this respect. Mercurochrome is decidedly ineffective as a germicide in the presence of blood, serum, tissue exudates and possibly other protein substances. Such substances interfered much less with the bactericidal action of tincture of iodine."

Thus the available experimental data indicates that while mercurochrome possesses some antiseptic action against certain organisms *in vitro*, its obvious limitations are such that it need not be considered further as a substitute for iodine in disinfection of the mucous membranes or skin.

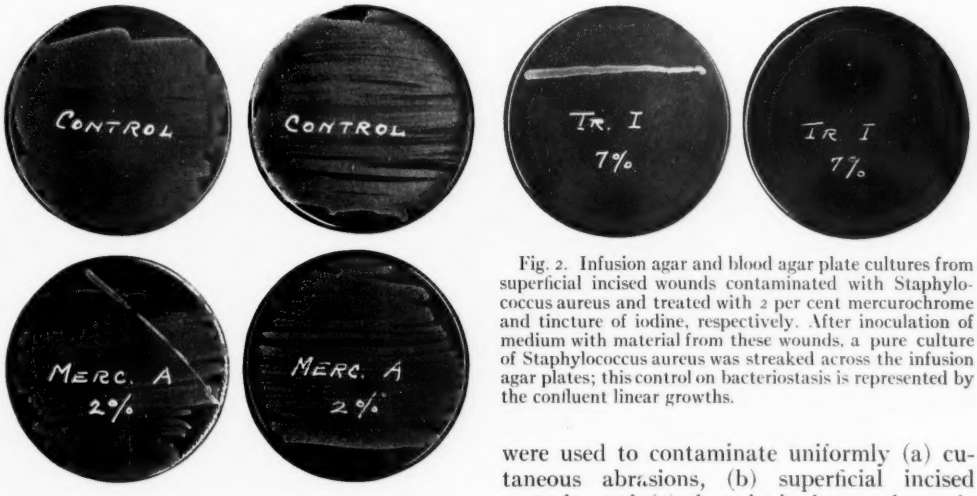

Fig. 2. Infusion agar and blood agar plate cultures from superficial incised wounds contaminated with Staphylococcus aureus and treated with 2 per cent mercurochrome and tincture of iodine, respectively. After inoculation of medium with material from these wounds, a pure culture of Staphylococcus aureus was streaked across the infusion agar plates; this control on bacteriostasis is represented by the confluent linear growths.

PRESENT INVESTIGATION—EXPERIMENTAL

The results of previous experiments, showing mercurochrome to be of relatively little value for pre-operative skin disinfection, suggested that the drug might be even less effective in the presence of such proteins as are to be encountered in wounds. However, because of certain unsubstantiated claims concerning the supposed effectiveness of mercurochrome under these conditions, the investigation was continued to include this phase of the subject.

Materials and methods. Several different solutions of both mercurochrome and iodine were tested as wound disinfectants, but a large proportion of the experiments were done with a commercially prepared solution labeled "Mercurochrome 2 per cent solution, dibromoxymercuri fluorescein, general antiseptic in place of iodine." Tincture of iodine was used in parallel control tests. These two solutions were selected purposely because both are commonly used as local applications on abrasions and superficial wounds. The bacteria considered in this report are Staphylococcus aureus and Streptococcus pyogenes. Because of the consistent resistance of these organisms to mercurochrome, the original plan to include species of spore forming bacteria was considered unnecessary. As in the experiments on skin disinfection, broth cultures or saline suspensions of the test organisms were used to contaminate uniformly (a) cutaneous abrasions, (b) superficial incised wounds, and (c) deep incised wounds made through the shaven abdominal skin of rabbits. The animals were immobilized on boards throughout the experiments. Sterile towels were used to protect the wounds in the tests requiring long exposure, and the necessary precautions against accidental contamination were observed. Within 5 minutes after adding the bacteria, the antiseptic solutions were applied to the contaminated wounds and to the adjacent skin for the desired periods of time, varying from 5 minutes to 3 hours. Cultures were then made to detect the survival of any viable test organisms, by collecting materials from each wound on moist sterile cotton swabs, which were immediately rubbed over the surfaces of blood agar, serum agar, or nutrient agar plates, and then used to inoculate flasks containing 100 cubic centimeters or more of beef infusion broth pH. (7.4 to 7.6). In each experiment, parallel cultures were made in a similar manner from untreated wounds, to furnish a comparison with results obtained in the tests; and, as usual, adequate controls were made to eliminate the possibility of confusion due to bacteriostasis in the test cultures. In a large number of experiments conducted under a variety of conditions, the following results were obtained:

I. *Disinfection of contaminated abrasions of the skin.* As indicated in Table I, a total of 42 skin abrasions, 30 contaminated with Staphy-

TABLE I.—DISINFECTION OF ABRASIONS OF RABBIT SKIN

	Duration of wound treatment (minutes)	Number of wounds treated with each drug	Number sterile after treatment with:	
			2 per cent aqueous Mercurochrome	Tincture of iodine
A. Contaminated with Staphylococcus aureus	5	18	None	15
	30	6	None	5
	120	6	None	5
B. Contaminated with Streptococcus pyogenes	5	6	None	3
	60	3	None	3
	120	3	None	3
Totals		42	None	34
Percentage of complete sterilization:			0	80.9

TABLE II.—DISINFECTION OF SUPERFICIAL INCISIONS OF RABBIT SKIN

	Duration of wound treatment (minutes)	Number of wounds treated with each drug	Number sterile after treatment with:		
			2 per cent aqueous	2 per cent alcohol-acetone-water	Iodine U.S.P. tincture
A. Contaminated with Staphylococcus aureus	5	42	None		35
	10	3	None		2
	15	8	None		6
	30	9	None		8
	60	11	None		10
	70	5	None		4
	120	9	None		8
	180	2	None		1
B. Contaminated with Streptococcus pyogenes	5	9	None	None	7
	10	2	None	None	2
	30	10		None	7
	45	1	None		1
	60	5	None	None	5
	120	4	None		4
	180	4		None	4
Totals		124	None	None	103
Percentage of complete sterilization:			0	0	83.0

lococcus aureus and 12 with Streptococcus pyogenes, were treated with mercurochrome. Cultures made from these treated lesions after 5, 30, and 120 minutes showed growth of the test organisms as follows: In one test with Staphylococcus aureus there was one colony in 2 there were 30 colonies, while in the remaining 39 tests the growth was as luxuriant as in cultures from the untreated control abrasions. In the parallel series of 42 abrasions treated with tincture of iodine, 8 showed growth of the test organisms in cultures as follows: four showed about one-fourth as much growth as the controls; two had 25 colonies each; one had 23 colonies and one had 3 colonies. All cultures from the remaining 34 abrasions were sterile. Thus, it is apparent that while mercurochrome caused very little reduction in the numbers of contaminating organisms and failed to sterilize any of the wounds, tincture of iodine resulted in sterilization in 80.9 per cent of the abrasions and in the remaining 8 caused a numerical reduction in the test organisms.

II. *Disinfection of contaminated superficial incised wounds.* The results obtained in bactericidal tests with superficial incised wounds are indicated in Table II. The 2 per cent aqueous solution of mercurochrome used on 89 such wounds contaminated with Staphylococcus aureus caused some numerical reduction of the organisms in 58 instances. In 23 of these tests the growth was about half as luxuriant as on control plates; in 10 it was estimated at one-fourth; while in 2 tests there were 5 and 10 colonies, respectively. Cultures from the remaining 31 wounds showed luxuriant growths similar to those obtained from untreated control wounds. This solution of mercurochrome used on 14 wounds contaminated with Streptococcus pyogenes failed to cause any appreciable decrease in the numbers of test organisms. Slightly better results followed the use of 2 per cent mercurochrome solution in water, alcohol and acetone on 21 wounds contaminated with Streptococcus pyogenes. In 8 of the tests there was some reduction in growth; 3 were reduced about one-half; one to about one-fourth; while 4 others showed 1, 2, 7, and 50 colonies, respectively. In the 13 remaining tests, the bacterial growths were luxuriant, resembling in amount the cultures from untreated wounds. Considering the results with mercurochrome as a whole, this drug was used on a total of 124 contaminated wounds, none of which was sterilized. Tincture of iodine used similarly on 124 wounds gave the following results:

Cultures from 89 wounds contaminated with staphylococci showed that 64 were sterile, while those from the remaining 15 showed a reduction in living organisms. In one there were 80 colonies; in 3 less than 50; in 4 less than 25, and in 7 less than 10 colonies each. Cultures from the 35 wounds contaminated with streptococci gave essentially similar results. Seven showed reduced growths; 1 had 80 colonies; 3 less than 25, and 3 less than 10 colonies each; while all cultures from the remaining 28 wounds were sterile.

To recapitulate, mercurochrome failed to sterilize any of the 124 superficial incised wounds in which it was used; while tincture of iodine was effective in 103, or 83 per cent.

III. *Disinfection of contaminated deep incised wounds.* The 2 per cent aqueous solution of mercurochrome was used on 32 deep incised wounds contaminated with Staphylococcus aureus and on 12 contaminated with Streptococcus pyogenes, with the results shown in Table III. Cultures from these 44 treated wounds showed luxuriant growths of the test organisms and there was no apparent numerical reduction except in 3 tests recorded as ++, +, and +, respectively. After treatment with tincture of iodine, cultures from 7 wounds showed a reduction of one-half (++); 11 tests showed a reduction of one-fourth (+); in 1 test there were 80 colonies; in 2 there were 30 colonies each; and in 4 there were 10 colonies or less. Cultures from the remaining 19, or 43.1 per cent of the wounds, were sterile.

TABLE III.—DISINFECTION OF DEEP INCISIONS OF RABBIT SKIN

	Duration of wound treatment (minutes)	Number of wounds treated with each drug	Number sterile after treatment with:	
			2 per cent aqueous mercurochrome	Tincture of iodine
A. Contaminated with Staphylococcus aureus	5	21	None	4
	60	5	None	3
	120	6	None	3
B. Contaminated with Streptococcus pyogenes	5	6	None	4
	60	3	None	2
	120	3	None	3
Totals		44	None	19
Percentage of complete sterilization:			0	43.1

SUMMARY

1. Three types of wounds—skin abrasions, superficial incisions, and deep incisions—contaminated with undiluted broth cultures of either Staphylococcus aureus or Streptococcus pyogenes were treated for various periods of time with solutions of iodine and mercurochrome, respectively.

2. Application of tincture of iodine to 151 wounds contaminated with staphylococci resulted in sterile cultures as follows: abrasions 83.4 per cent; superficial incisions 83.1 per cent; and deep incisions 31.2 per cent; while its use on 59 wounds contaminated with streptococci resulted in sterilization as follows: abrasions 75 per cent; superficial incisions 80.9 per cent; and deep incisions 82 per cent. In brief, of 210 contaminated wounds treated with tincture of iodine, the cultures from 156, or 74.2 per cent, were sterile.

3. Mercurochrome used under similar conditions caused relatively little reduction in the numbers of viable test organisms and failed to sterilize any of the 210 wounds.

CONCLUSION

The 2 per cent aqueous solution of mercurochrome advocated for the first aid treatment of wounds is a relatively weak antiseptic. When used experimentally for the destruction of Staphylococcus aureus or Streptococcus pyogenes in abrasions or incised wounds, it was decidedly less bactericidal than tincture of iodine. Mercurochrome is comparatively so ineffective in the sterilization of contaminated living tissues that it should not be considered as a substitute for iodine.

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EXCRETION UROGRAPHY BY MEANS OF THE INTRAVENOUS AND ORAL ADMINISTRATION OF SODIUM ORTHO-IODOHIPPURATE: WITH SOME PHYSIOLOGICAL CONSIDERATIONS[1]

PRELIMINARY REPORT

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ALTHOUGH the original contribution to excretion urography with the use of iopax (uroselectan) as described by the author (11) has proved useful in the clinical investigation of the urinary tract (7), certain desirable features have been wanting. The present paper deals with another substance,[2] newly developed for excretion urography, and is based upon the physiological principle of detoxification and on other metabolic considerations. The fundamental concept of this work is the utilization of an organic nucleus, representing a normal product of animal metabolism, as a carrier for the radiopaque element necessary for the X-ray visualization of the urinary tract. The compound now proposed is sodium ortho-iodohippurate, a halogen derivative of a substance normally found in the human urine.

In the consideration of a new substance to be used for excretion urography, the following were the guiding principles:

a. That the substance be highly soluble and approximate the hydrogen-ion concentration of the blood.

b. That the radiopaque halogen be bound in a stable form to an organic nucleus.

c. That the nucleus be one which is produced in the course of animal metabolism.

d. That it be highly water soluble. A high degree of water solubility is generally paralleled by a greater tendency for rapid absorption and excretion, and also permits the intravenous administration in small volume. Moreover, a substance that is readily and rapidly excreted from the body is less apt to produce toxic manifestations. In this connection it is also important to note that organically bound iodine for excretion urography has been found to be well tolerated by the human body and not associated with the picture of iodism.

e. That the substance be a sodium salt, since the sodium ion is most suitable from a physiological standpoint.

f. That the substance be selectively and rapidly excreted by the kidney in high concentration.

g. That it be well tolerated.

h. That it be comparatively inexpensive.

Of the metabolic studies already reported concerning benzoic and hippuric acids, the following points appeared noteworthy and promising in the development and rationale of the present investigations:

a. The introduction of benzoic acid or its sodium salt into the animal organism results in its conjugation with glycine and in the excretion of hippuric acid or its sodium salt in the urine. In similar fashion it has been shown that the administration of iodobenzoic acid in the dog and rabbit results in the urinary excretion of iodohippuric acid (Novello, Miriam, and Sherwin).

b. The synthesis and elimination of hippuric acid after benzoic acid administration represent processes of detoxification (Csonka, Griffith and Lewis, Raiziss and Dubin, Lewinski, Dakin, and Lewis).

c. Sodium hippurate is a very suitable organic parent-substance for combination with iodine or bromine, since (1) it is extremely soluble in water, (2) is neutral in solution (Corfield and Melhuish), (3) represents a product of metabolism, (4) is well tolerated, and (5) is quantitatively excreted (95 per cent in 6 hours after the intravenous administration to the rabbit (Raiziss, Raiziss and Ring, Griffith and Lewis, Csonka, Lewis).

With these observations and considerations in mind and after consultation with Dr. Sobotka, to whom thanks are expressed for

[2] This new medium for excretion urography is as yet not procurable for general use.

[1] From the Second Surgical Service, the Roentgenologic and Laboratory Divisions, the Mount Sinai Hospital, New York. Work carried with the aid of a grant from The Emanuel Libman Fellowship Fund.

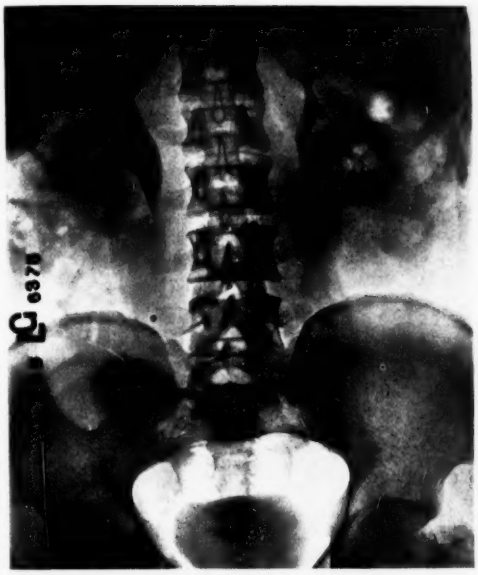


Fig. 1. Intravenous urogram, man, 38 years old. Normal urinary tracts. 10 grams of substance administered.

Fig. 2. Oral urogram, man, 32 years old. Dilatation of both kidney pelves. Kinking of right ureter. Underlying condition—urethral stricture. Fifteen grams of substance administered.

kind co-operation, the author carried out a series of experiments, resulting finally in the demonstration that sodium ortho-iodohippurate possesses the necessary qualifications.

In accordance with the present investigations this substance proves to be a non-toxic, highly soluble, neutral and radiopaque salt which is selectively excreted through the urinary tract in sufficiently high concentration to yield satisfactory urograms.

Sodium ortho-iodohippurate (38.8 per cent iodine) is easily soluble in less than its own weight of water and can be prepared and distributed in sterile solution ready for use. The solution remains unchanged in color or reaction after sterilization or on standing. The iodine exists in a stable organically bound state. Iodism has never been observed. The tolerance for this compound is good. Rabbits usually tolerate 2 to 2.5 grams of substance per kilogram of body weight administered intravenously in 30 per cent concentration over a period of about 10 minutes. Patients suffering from tuberculosis or Graves' disease have not shown reactions after injection. Manifestations of injury to the kidney, as demonstrated by urine analysis in the human as well as tissue examination in the rabbit, have not been observed. Microscopic examination of the liver, lung, and heart similarly fails to reveal evidences of injury. The tissues selected for examination have been obtained from rabbits killed 24 hours to 4 months after injection. The substance is excreted as such through the urinary tract and may be recovered as the insoluble acid on the addition of a dilute mineral acid. On recrystallization from hot water with the aid of charcoal, the recovered sub-

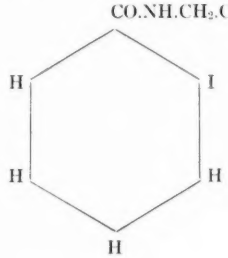
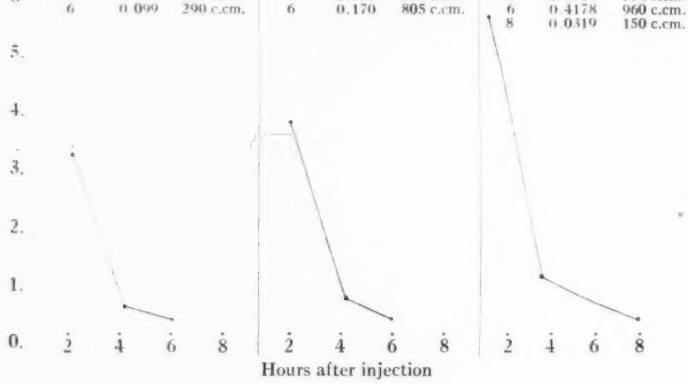


TABLE I

	Ten gram dose			*Fifteen gram dose*			*Twenty gram dose*		
Gm.	Hrs.	Iodine	Volume	Hrs.	Iodine	Volume	Hrs.	Iodine	Volume
6	2	3.13	302 c.cm.	2	3.857	160 c.cm.	2	5.70	396 c.cm.
	4	0.34	280 c.cm.	4	0.551	595 c.cm.	4	0.8713	754 c.cm.
	6	0.099	290 c.cm.	6	0.170	805 c.cm.	6	0.4178	960 c.cm.
							8	0.0319	150 c.cm.



stance appears white and crystalline. Identification of this substance has been accomplished by means of melting point, nitrogen, and iodine determinations. The urines from patients injected with sodium ortho-iodohippurate have never shown positive Fehling or Benedict reactions, indicating that the formation of iodo-benzoic acid and its subsequent excretion and conjugation with glycuronic acid is unlikely. Furthermore, the quantitative determinations of the recovered substance would speak against the presence of either excreted free iodobenzoic acid or iodobenzoyl glycuronic acid.

Normally from 90 to 95 per cent of the substance can be recovered from the urine within 8 hours after the injection (based upon iodine determinations). Between 70 and 80 per cent (in terms of iodine) is recovered during the first 2 hours and between 60 and 66 per cent is excreted in the first hour. Table I illustrates the curves of excretion in normally functioning kidneys obtained after the administration of 10, 15, and 20 gram doses respectively. From these results it is evident that the normally functioning kidney excretes this substance in a high concentration and within a short period.

It is evident that a certain concentration of the radiopaque element, the iodine, is necessary for roentgenological visualization. This concentration depends upon renal and extrarenal factors influencing renal excretion as well as upon the dose administered. Broadly speaking, good visualization, poor or no visualization is dependent upon the above enumerated factors. Other considerations bearing upon the relationship between renal function and roentgenological visualization are discussed in other publications.

Therefore, as in the case of other substances developed for excretion urography, so with sodium ortho-iodohippurate: it is essential to bear in mind the factors governing renal excretion when evaluating this method and the results obtained with it.

Procedure and reactions. Satisfactory urograms have been obtained in adults with doses varying between 10 and 15 grams of substance dissolved in distilled water in 40 per cent concentration. The injection is carried out over a period of 5 minutes. The first film is taken 10 minutes after the injection, two subsequent exposures being made at 20 minute intervals. Whenever functional disturbances are present additional films should be taken to determine definitely the absence of visualization or the presence of late visualization. Aside from a slight sensation of generalized warmth, there have been no reactions. Thrombosis at the site of injection has not been observed. To date 125 cases have been injected, 20 and

grams of substance having been administered in some cases; with the larger dose occasionally transient vomiting occurs. Children under 13 years of age have received 10 gram doses without ill effects. A one year old child, in whom suitable roentgenograms were observed, showed no reactions from a 10 gram dose. In a 3 year old child receiving 6 grams of substance satisfactory roentgenograms were also obtained.

Oral administration in the human has given encouraging results. Of 14 cases 50 per cent yielded satisfactory urograms. The dose administered by mouth has been between 10 and 15 grams dissolved in simple syrup. No reactions have been noted; diagnostic pictures have been obtained 90 and 135 minutes after administration. It appears that the results by the oral route will not be as consistently good as by the intravenous one. Further investigations with the oral administration are in progress in the hope of improving the results.

Of great aid in obtaining clearly defined and readable urograms is the application of a moderate degree of compression by means of an air-inflated balloon over the region of the urinary bladder. A more detailed consideration of this aspect is dealt with in other publications.

Field of application and contra-indications. In order to avoid repetition, the reader is referred to the literature dealing with excretion urography wherein these phases are discussed.

Additional investigations with related substances, such as the sodium salts of meta- and para-iodohippuric acids, diiodohippuric acid and of bromoiodohippuric acid, iodobenzoyl urea, and finally the administration of monoiodo- and diiodobenzoates of sodium in conjunction with glycine by the intravenous and oral routes are being continued.

SUMMARY

The author presents sodium ortho-iodohippurate for excretion urography. It is felt that this substance has the following advantages:

1. It is relatively inexpensive.
2. It is without toxic effects.
3. It can be administered in a small volume of diluent.
4. A relatively small quantity of the salt is required for satisfactory urograms.
5. It yields satisfactory roentgenograms.
6. Satisfactory results have been obtained by the oral route.

The author wishes to express his gratitude to Mr. Albert P. Sachs and the Zonite Products Corporation for their invaluable assistance; to Drs. Beer, Gross, Jaches, and Libman for their kind co-operation.

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THE USE OF ANTICOLIBACILLARY SERUM IN SURGERY[1]

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I HAVE shown that certain strains of Bacillus coli possess, both experimentally and in human infection, a considerable virulence and toxicity which in man may be manifested by medical and surgical conditions of great gravity. I have also shown that Bacillus coli (the atypical as well as the normal strains) has the power of secreting two toxins, one a neurotropic thermolabile exotoxin, the other an enterotropic and hepatotropic thermolabile endotoxin. The association of these two toxins produces a pathological state that determines the widely varying phenomena which accompany colibacillary septicæmias, as well as acute or chronic local colibacillary infections. Such a pathological state explains the nervous troubles observed in chronic enteropathies (particularly mucomembranous enteritis), paralyses, etc., which are brought about by the exotoxin. The endotoxin affects particularly the glands of Lieberkuehn, the biliary secretion, and the hepatic parenchyma. It produces severe symptoms, such as diarrhœal crises. The toxi-infection may even terminate in icterus gravis or acute yellow atrophy of the liver (H. Vincent).[2]

My clinical and experimental researches have led me to the preparation of an antitoxic and anti-infectious anticolibacillary serum. This serum injected into patients suffering from very grave medical conditions: bacillus coli septicæmia, cholecystitis of the same origin, suppurative pyelonephritis (in adults of all ages, pregnant women, children), chronic enterocolitis, paralyses of colibacillary origin, etc., brings about a rapid recovery, such as I have already reported.[3]

Moreover, Bacillus coli commonly brings about maladies which interest the surgeon in particular. It has, therefore, seemed worth while to point out the effect that this new anticolibacillary serum may produce in affections of a surgical nature.

Few organs escape infections due to the colon bacillus, but in general the abdominal viscera are the ones most frequently affected by this micro-organism, because it lives normally in their vicinity, i.e., the intestine. The peritoneum, on account of traumatisms of the intestine (contusion, wounds by penetrating instruments, gunshot wounds, etc.), is frequently invaded by micro-organisms of the digestive tract. One of the most common as well as the most dangerous, is certainly Bacillus coli. Perforative or gangrenous appendicitis constitutes equally one of the most important indications for anticolibacillary serotherapy. Pyosalpingitis is the expression of very diverse infections, among which those by Bacillus coli are very common. The same is true of pelvic abscesses. In all of these affections it is advantageous, before injecting the serum, to make a microbiological examination.

Primary suppurative pyelonephritis of Bacillus coli origin requires as early application as possible of serotherapy. This malady, as I shall show, is rapidly cured by this method. In pregnancy and in the puerperium, when the bacillus has invaded the blood and has lodged, as a result, in the renovesical apparatus, the infectious symptoms disappear within a few days. I shall review the principal surgical maladies in which serotherapy serves as a particularly efficacious aid to the surgeon and operator.

Statistics of mortality from gangrenous appendicitis with perforation and late operation indicate a death rate of 7 cases out of 10 (Cook, of Nancy; Vielle, of Bordeaux); 3 cases out of 6 (Dr. Foisy); 70 per cent (Racovatz), etc.

Gangrenous appendicitis constitutes one of the most important indications for sero-

[2] H. Vincent. Soc. de Biol., 1893, May 12.

[3] H. Vincent, C. R. Soc. de Biol., 1922, lxxvii, 642; Compt. rend. Acad. d. Sc., 1925, clxxx, 239; ibid., pp. 407, 1033, 1623; Compt. rend. Acad. d. Sc., 1928, clxxxvii, 407; ibid., 1928, clxxxix; Bull. de l' Acad. de Méd., 1926, Nov. 27; 1929, Mar. 19; 1930, April 29; La Riforma medica, 1930, No. 36; Vida Nueva, Mar. 15, 1931; Am. J. M. Sc., 1932, clxxxiii, 301; Mil. Surg., 1932, lxx, 313-322.

[1] Translated by Edgar Erskine Hume.

therapy.[1] This serum is, in fact, a precious adjuvant to surgical intervention. Bacillus coli is the agent almost constant in peritonitis, so often fatal, and in septicæmias of appendicular origin. This bacillus exists on the surface of the appendix, and in the pus, in prodigious quantities. I have recovered it sixteen times in seventeen cases of gangrenous appendicitis from the cloudy or purulent fluid surrounding the necrotic appendix. The anaerobes Bacillus perfringens, Bacillus fragilis, Bacillus funduliformis, Bacillus fusiformis, etc., are much more rarely present (about one in four), and in small numbers. Nevertheless, before operating in such cases, I advise the administration of multivalent antigangrenous serum,[2] or anticolibacillary serum, the one or other, introduced into the operative field and injected simultaneously under the skin.

This is the technique systematically employed in various surgical services, notably at the Val-de-Grâce (Professors Duguet, Clavelin, Paître, Lacaze, and others), by Dr. Foisy of Chateaudun, by Dr. Guibal of Béziers, by Professor Forgue of Montpellier, by Professor Laffitte of Niort, and other surgeons. This treatment brings about "ideally simple" recovery (Clavelin). It prevents the too frequent dangers which accompany gangrenous appendicitis with perforation and peritonitis in operations of necessity (Dr. Foisy, surgeon in chief of the hospital of Chateaudun).

I shall give two examples from among many others:

Louis S., aged 21 years, admitted to the Val-de-Grâce, December 3, 1928, in the service of Professor Paître. The onset was 48 hours previously, but the symptoms had become markedly worse 10 hours before arrival at hospital, and consisted of greenish vomiting, hiccough, ballooning of the abdomen, and generalized contraction of the walls. There had been passage of gas for 10 hours. Intestinal obstruction and general condition were grave. Temperature 103.1 degrees; pulse 140 and hardly perceptible. The operation by Dr. Lacaze showed the appendix gangrenous, in the terminal two-thirds, and ruptured into the peritoneal cavity, without any walling off. Small stercoral calculi were found in the free peritoneum, and abundant cloudy foul-smelling fluid in all the peritoneal folds and the pouch of Douglas. The intestinal loops were dilated, red, and like ground glass in appearance. After operation 60 cubic centimeters of anticolibacillary serum and 20 cubic centimeters of multivalent antigangrenous serum were injected subcutaneously, the dose being repeated on the following day. The treatment was continued in diminishing doses, and the temperature returned to normal on the fourth day. Six days after operation the drains were removed. Aside from the serum reaction, recovery was uneventful.

In this serious case of gangrenous appendicitis with widely diffused peritonitis, there followed extremely simple and rapid recovery under the treatment.

In the following case, reported to me by Dr. Machavoine, former interne, Hôpitaux de Paris, there is another remarkable example. It may be summed up thus:

Treatment of generalized peritonitis after perforation of appendix, by Vincent's anticolibacillary serum and hypertonic salt solution. Recovery.

The patient was a young woman of 25 years, stricken November 7, 1928, with gangrenous appendicitis with perforation of the appendix, followed by acute peritonitis. Operation 48 hours afterward, was difficult and prolonged (1¼ hours). The patient was transported in emergency to the clinic by automobile, over a rough road 60 kilometers long. The surgical intervention was, of necessity, done under the most unfavorable conditions. There was present a quantity of foul liquid which "flowed out in all directions." The entire appendix was gangrenous and perforated. On the following day, November 10, the patient was in a state of profound shock and in extremely grave condition. There were ballooning of the intestines, hiccough, vomiting, fæcal retention, etc. Pulse was about 110. The usual treatment (glucose solution, cardiac tonics, etc.) was given, "but without much hope," according to the surgeon, "because the patient seemed lost."

On November 11, there was administered the first injection of 60 cubic centimeters of anticolibacillary serum which had been procured in all haste from Paris. The injections were continued, 40 cubic centimeters being given every 4 hours on November 12, 13, and 14. At this time the danger seemed to be over, and it was not considered necessary to continue the anticolibacillary serotherapy. As the patient showed signs of intestinal obstruction, there were given on November 12 and the two days following, intravenous injections of hypertonic salt solution by Grosset's method. "The situation which had seemed desperate and which was becoming worse, was miraculously transformed" (Dr. Machavoine). Finally the patient left the surgical clinic on December 2 entirely cured of the serious symptoms which had seemed to point to certain death.

[1] H. Vincent, J. méd., Brux., 1925, May; idem, J. méd., Montpellier, 1926, Nov.; idem, Internat. Clin., 1926, xxxvi, 161; idem, Progres recents en Thérapie anti-infect, Paris, J. B. Baillière et fils, 1926, 262; idem Bull. Acad. de méd., 1928, Nov. 27 and 1929, March 19.

[2] H. Vincent and G. Stodel, Compt. rend. Acad. d Sc., 1918, clxvii, 237, 245, 305; ibid, 1919, clxviii, 188.

Dr. Foucalt of Poitiers also published a series of observations of appendicitis with perforation and with beginning peritonitis or even with generalized peritonitis, which were cured by surgical intervention aided by serotherapy. One of the most remarkable cases was that of a little girl, aged 8 years.

The surgeon saw her for the first time "in a state of diffused peritonitis of appendicular origin," with the abdomen ballooned out, fæcal vomiting, pulse 158, and temperature 99 degrees. The case was 48 hours old, and the mother had purged the child the day before. When the abdomen was opened, the peritoneal cavity was found to be full of pus, as were the right iliac fossa, pouch of Douglas, and left iliac fossa. The general condition was very grave. Operation was done under novocain. At the same time anticolibacillary serum was injected. After 24 hours the pulse had dropped to 110 and the general condition, so desperate the day before, showed "great amelioration." After 48 hours the improvement was even more noteworthy. The pulse was 80. The child recovered. "She had, however, been considered as lost, and intervention had been done *in extremis*."

Dr. Laffitte of Niort has reported similar cases to me.

In cases of generalized peritonitis of appendicular origin in which prognosis is fatal, one cannot advise too strongly the injection very early of large doses of serum: 60, 80, or 100 cubic centimeters in adults; 40 cubic centimeters in children, renewing the injections as often as necessary, and diminishing the dosage when the general and local conditions are both improving.

These facts demonstrate what great security such serotherapy brings to the surgeon, and that one may employ this method in gangrenous appendicitis complicated by localized or even generalized peritonitis.

The same method used in pelvic abscesses, and, in a general way, in neighboring suppurations of the intestine, when Bacillus coli is present or abundant in the pus, may be of great service to the surgeon. Often such suppurations, the point of departure of which is a lesion or traumatism of the digestive tract, are produced by the many microorganisms from the intestine: anaerobes, enterococci, streptococci, and at times even the Bacillus fusiformis and Spirochæta vincenti. The presence of the colon bacillus suggests the use of the anticolibacillary serum, but when anaerobes are associated therewith, one must inject simultaneously the multivalent antigangrenous serum of H. Vincent and G. Stodel, as we have advocated in the treatment of gangrenous appendicitis, as well as the new antistreptococcic serum prepared by my method, which is particularly active even in septicæmia verified by hæmoculture.

Iliac abscesses, before and after surgical intervention, often require subcutaneous injections of anticolibacillary serum, and even perisigmoidal and perirectal abscesses. The serum, in these affections, is a precious adjuvant for the surgeon. It is also useful to introduce a certain quantity into the field of operation.

Bacteriological study of suppurative salpingitis may demonstrate Bacillus coli. In such cases it is also very useful, as has been shown by Chevassu, surgeon of the Cochin Hospital, to introduce the anticolibacillary serum into the field of operation, and to inject the same serum subcutaneously for 2 or 3 days (20 to 40 cubic centimeters per day). Thus one brings about a sharp drop in the fever and prevents an extension of the infection or its general dissemination through the blood stream.

The urinary tract, in woman as well as in man, is the seat of predilection of the colon bacillus. Basseler has found Bacillus coli in the urine of healthy subjects 18 times in 191 instances. But this observation should be verified. It is the same in the cases of William Esthel who reports no less than 36 per cent of urinary colibacillosis in patients who are affected with constipation or intestinal affections.

In pathological states, the bacillus appears in the urine, either primarily or secondarily, in surgical affections, of the kidney, ureter, bladder, and urethra; and colibacilluria is extremely frequent. All maladies of the renovesical apparatus: lithiasis, hydronephrosis, cystic kidney, benign or malignant tumors, urethral stricture, prostatic hypertrophy, etc., all encourage colibacillary localization. In some cases renal tuberculosis is complicated by the same infection and prognosis becomes particularly grave.

Explorations of the bladder and ureters may result in the ensemination of the urinary passages with various bacteria, among which Bacillus coli is the most common.

These maladies, in which the colon bacillus has developed secondarily, justify, above all, surgical treatment; it is upon such treatment that recovery depends. Serotherapy obviously can do nothing in renal or vesical calculus, tumors, prostatic adenoma, urethral stricture, etc.

However, in these maladies, as long as the determining cause persists and keeps up the local infection, serotherapy is an adjuvant to surgical treatment. And even when surgical treatment has already been instituted, anticolibacillary serotherapy can be used as a necessary complement to such treatment, in combating the multiplication of the bacilli and against their becoming generalized, which is so often a danger.

And so, according to Hunt's statistics, 16.5 per cent of patients operated on for hypertrophy of the prostate, die of septicæmia. Bacillus coli is the common agent in these fatal infections. In the urological services of the Cochin Hospital in Paris, the hospital of the Val-de-Grâce, the Hospital of Montpellier, etc., the serum is systematically utilized in this manner, and very effectively.

It is customary to recommend, also as a prophylaxis, anticolibacillary serotherapy in patients who must submit to operation on the urinary tract, when they are already infected. The injections of serum (20 cubic centimeters per day) are given on the day before, the day of operation, and the following day. It is especially in nephrectomy, renal or vesical lithiasis, or in the removal of the prostate, that this prophylactic measure is indicated.[1]

Primary suppurative colibacillus pyelonephritis,[2] recent or remote, is usually cured in a few days by serotherapy, with or without lavage of the renal pelvis and bladder.

As is well known, primary suppurative pyelonephritis is sometimes a complication in various infectious states: grippe, typhoid fever (H. Vincent), malaria (H. Vincent), bacillary or amœbic dysentery. They may accompany or follow colon bacillus septicæmia: I have shown that in 47.5 per cent of cases, patients with primary pyelonephritis of Bacillus coli origin, have in their history chronic appendicitis, with or without operation. Stubborn constipation is a very common cause of colon bacilluria.

The colon bacillus may find lodgment and grow in the kidney when some mechanical obstacle hinders the passage of fæcal material in the intestine (compression of the intestine by a tumor, by pregnancy, chronic enterocolitis, intestinal ptosis, etc.). It is the same when the passage of the urine is impeded or blocked by compression of the kidney, or the ureter or by renal ptosis.

In all these cases Bacillus coli has the intestine as its point of departure. It is, moreover, frequently accompanied in the lesions and in the urine, by other microorganisms of the same origin: enterococcus and staphylococcus above all. I have more rarely found micrococcus tetragenes, proteus vulgaris, the streptococcus, the bacillus of Friedlaender, the pseudodiphtheria bacillus, certain anthracoides bacilli, a very markedly Gram negative bacillus, certain anaerobes, etc.

It is of primary importance, before practicing serotherapy, to make a careful cytological and bacteriological study of the urine, and to verify by cultivation on appropriate media (lactose broth, neutral red broth, litmus milk, various sugars, etc.) the identity of the Bacillus coli isolated in the urine. A superficial examination may lead to errors of diagnosis of the micro-organism. According to my experience, in 18 per cent of cases, the urinary infection has been found to be of other organisms than the colon bacillus.

Leaving the intestine, the renal infection is followed nearly always, as I have myself shown, by a blood infection, sometimes severe, sometimes light. It gives rise, at times, to extensive histological lesions, especially of multiple areas of suppurative glomerulitis, and periglomerulitis, with enormous accumulations of bacilli in these infected foci and in the uriniferous tubules.

[1] When patients have already received therapeutic injections of horse serum, it is necessary to desensitize them by one or two preliminary injections of 1 cubic centimeter (or if necessary by three injections of 1 cubic centimeter) of serum, 3 hours before the principal injection of 20 to 40 cubic centimeters. I advise this even in adult subjects who have never previously been subjected to injections of horse serum.

[2] Without any of the renal, vesical, or ureteral lesions mentioned in the previous section.

Suppurative pyelonephritis due to Bacillus coli is fairly often complicated by cystitis. The urine contains a large number of damaged polynuclear leucocytes, desquamated cells of the renal pelvis, ureters, and bladder, and red blood cells.

The co-existence in the urine of the enterococcus, the staphylococcus, and the micrococcus tetragenes, does not introduce, in my opinion, any element of special gravity, and places no obstacle to healing with use of anticolibacillary serum. In two patients suffering from old suppurative pyelonephritis following pregnancy, the urine showed simultaneously the presence of Bacillus coli and the enterococcus. But anticolibacillary serotherapy brought about entire recovery. The enterococcus persisted for several months after the disappearance of the Bacillus coli, and then it disappeared itself.

Other patients with serious forms of colon bacillus pyelonephritis, with association of the staphylococcus and the tetragenes, were similarly completely cured after injections of serum.

The association of the streptococcus is much more serious. It obviously demands the use of mixed serotherapy by anticolibacillary serum and the new antistreptococcic serum.

Thus we see that the anticolibacillary serum has a very marked and very rapid curative effect on all forms of suppurative and primary pyelonephritis, whether they be of long standing or recent. Serotherapy has cured infected patients with purulent urine which had existed for from 3 to 5 years, and even 10 years in one case that was reported to me.

It is not my purpose to publish here all these cases. I have taken only one example showing the rapid action of the serum in a very serious case. I have reported many others to the Academy of Medicine of Paris.

Mme. H., 42 years of age, in 1922, following her first pregnancy, had subacute febrile enteritis which was probably the first stage of the infection which passed soon into a chronic condition. Her urine became purulent. Pyelonephritis complicated the course of her second pregnancy. The urine was filled with pus, numerous colon bacilli and staphylococci. Nine injections of autovaccine produced no result.

The labor was difficult, hæmorrhage being abundant. From this time on her condition became one of extreme gravity. The urine was highly purulent, and there were febrile attacks, renal pain, continuous phenomena of spasmodic enterocolitis, wasting, extreme anæmia, and complete adynamia. "The patient," said the physician who was treating her, "led a lamentable existence" (Prof. A. Lippens of Brussells). The condition had resisted all treatment and the most severe regimen. It had continued for 5 years.

In 1928, she was given four subcutaneous injections of 40 cubic centimeters each of anticolibacillary serum. The urine, which up to that time had been a bacterial reservoir and full of pus, became perfectly clear and sterile. "In a few days the patient was transformed. She had not felt so happy for five years" (Dr. A. Lippens). All the morbid symptoms—pyuria, renal pain, chronic enterocolitis, fever, prostration, mental depression, etc.—disappeared completely in a few days. Several months afterward I was informed that her condition was still excellent. Her appetite had become normal, she had returned to her former weight, "she had the bright and rosy expression of a woman in good health." The sterility of the urine has, since that time, continued. Examples of the same nature are today extremely common.

In a general way I have noted this apparently paradoxical fact that the graver the suppurative colibacillary pyelonephritis whether acute or of long standing, and accompanied by very marked general phenomena,—fever, symptoms of infection, etc.—the more rapid is the recovery under the influence of the serotherapy. A great number of authors (Prof. M. Chevassu, Prof. A. Maisonnet, Prof. Jeanbrau, Drs. P. Roger-Petit, Leenhardt, Minet, Vérain, Trocmé, Dayras and R. Bernheim, Darget, F. Charles, and Noguès, P. Charpy, Grandineau, etc.) have published cases in which they have observed and verified these results.

Pyelonephritis of infants may, as I have already said, be unrecognized because the urine of infants is mixed with the other dejecta in the napkins. The condition may be marked by fever, diarrhœa, vomiting, extreme wasting, and rapid death. Bronchopneumonia is sometimes added to this syndrome, already so dangerous. But dealbuminized anti-colibacillary serum injected subcutaneously in doses of 20 cubic centimeters during 5 or 6 days, caused rapid recovery of these little patients.

In adults treated by the serum it is often necessary to give, on the fourth and on the

seventh day of the treatment, one or two lavages, first of the diseased renal pelvis, a 1 per cent solution of silver nitrate being used; and second of the bladder, with a solution of 1:1000 or 1:1500, because the antibodies carried by the serum in massive doses do not always penetrate into the urine. When the kidney is damaged it allows the passage of albumin, and with it antibodies in quantity sufficient to destroy the bacilli in the kidney pelvis and bladder. In these cases the urine becomes sterile about the eighth to the tenth day, and it is not necessary to practice lavage.

The example cited above shows that the serum alone may be sufficient to bring about sterilization of the kidney and of the urine. But antiseptic lavage of the renal pelvis and bladder assures the cure with more certainty because it destroys the residual bacilli which have persisted in these cavities.

Disinfection of the renal pelvis and bladder is not of itself sufficient to cure the patients, because it is without action on the renal parenchyma. The majority of the patients whom I have observed were treated by this silver disinfection, associated with vaccines, autovaccines, bacteriophages, chemical antiseptics, etc., without any result. One patient aged 28 years, who had submitted for 3 years to lavage of the renal pelvis and bladder, continued to have very purulent urine. Five injections of serum brought about a complete cure, although the young woman had at the same time a mild degree of hydronephrosis.

The most resistant forms of urinary colibacillosis are those which are not accompanied by the presence of pus in the urine, or in which the urine shows only rare polynuclear leucocytes. These are the forms that I have called "stabilized" colibacillosis. However, one may bring about their cure by prolonging the injections of serum for a week or more, carrying out, during this period and afterward, the disinfection of the diseased renal pelvis and bladder, repeated two or three times. Anticolibacillary serotherapy is, then, the surest and most efficacious method of treatment of primary suppurative pyelonephritis, whether acute or chronic.

Although it acts in all stages, it is preferable to inject the serum early in the pyelonephritis, when the phenomena are most acute, the urine is filled with pus, and the fever is high.

It is useless or contra-indicated to associate with it any other chemical or vaccinal treatment. The use of vaccine and autovaccine or even the bacteriophage, has been known to provoke in selected cases the development of more resistant strains of colon bacilli. On the other hand, by using other means of treatment one may precipitate, almost fatally, this very stubborn pathological state that I have called "stabilized colibacillosis," which is the most resistant form of infection.

It is desirable to call attention to the necessity, in patients recovered from pyelonephritis, of remembering that the morbid state which induced the renal infection still persists. After such recovery, one should watch the digestive tract and appendix, combat constipation, treat visceral and intestinal ptoses, consider the gall bladder, give advice as to prudent alimentary and general hygiene, and send the patient, after the cure, to the country, or if the nervous condition permits, for a sea voyage, or possibly to certain of the hydro mineral resorts, such as those of La Preste or Capvern in France.

The persistence of the cause which in the first instance determined the invasion of colon bacilli may lead ultimately to a new infection of the kidney, after a year or more, in subjects who have recovered bacteriologically.

Consequently a primary infection, even when prolonged, of the kidneys by the colon bacillus does not necessarily confer, after treatment, immunity of these viscera against a new attack of the same infectious agent.

CLINICAL SURGERY

FROM THE MEMORIAL AND THE FIFTH AVENUE HOSPITALS

THE ORIGINAL JANEWAY GASTROSTOMY

HAYES E. MARTIN, M.D., AND WILLIAM L. WATSON, M.D., F.A.C.S., NEW YORK, NEW YORK

IN 1913, the late H. H. Janeway published a description of his original technique for gastrostomy. The main principle of the Janeway operation is the construction of a narrow plastic tube from a full thickness flap of stomach wall. This tube leads from the stomach cavity to the skin and furnishes a gastric fistula entirely lined by mucosa rather than by granulation tissue as in most other methods. In his report of 5 cases, Janeway used a left, upper mid-rectus incision and led the plastic tube out through the operative wound. He later modified this technique by using a longer midline incision between the xiphoid and the umbilicus and brought the plastic tube out through a stab wound in the middle of the left rectus, just below the costal margin. This modification then became the standard technique at Memorial Hospital and was described by Quick and one of us in 1928, at which time we reported a series of 172 cases with a mortality of 18 per cent.

An analysis of the causes of postoperative death in this series revealed that many were due to complications resulting directly from the operative procedure such as infection and subsequent separation of the edges of the midline operative incision. Wound infection is, of course, both a more common and a more serious complication in the debilitated subjects in whom gastrostomy is indicated.

In our efforts to lower this postoperative mortality, we returned again to the original Janeway technique, making a short (about 6 centimeter) incision through the middle of the left rectus, just below the costal margin, delivering a portion of the anterior wall of the stomach, constructing the plastic tube, and fixing it in the upper angle of the wound. This change in technique has been followed by a remarkable improvement in the postoperative mortality. Since 1928, we have performed gastrostomy by this technique in 52 cases, with a mortality of 3 (5.8 per cent). We believe that these 3 postoperative deaths were incidental or due to the disease (carcinoma of the œsophagus) rather than to the operation. The mortality will be discussed further, later in this report.

The reasons for this improved mortality with the change in technique are quite readily understood. The body of the stomach or corpus ventriculi from which the plastic tube is to be constructed lies directly under the upper portion of the left rectus muscle and the adjacent costal margin. Therefore, a short, upper left mid-rectus incision will permit a more direct and an easier access to this portion of the stomach than a much longer midline incision. In the majority of cases, as soon as the peritoneum is opened, the anterior wall of the stomach is seen lying directly in view. With a sponge forceps a sufficient portion is delivered through the wound to permit the entire operative procedure on the stomach to be done outside the abdominal cavity. Since no retractors are required after the stomach is delivered, there is little discomfort and practically no surgical shock. After the construction of the plastic tube, its attachment in the upper angle of the incision and the closure of the operative wound is quickly accomplished in a few minutes. Since the whole procedure is done with a minimum exposure and a minimum manipulation within the abdominal cavity and of the wound edges, infection should seldom occur with good technique. Gastric contents, will, of course, sometimes contaminate the wound edges with subsequent wound infection, but in our series never resulted in separation of the fascia and caused no mortality and a very slight morbidity.

The location and behavior of the operative incision is perhaps more important in this operation than in many others. Janeway abandoned the left rectus incision because of too frequent infection and breaking down of the wound with subsequent detachment of the plastic tube from its moorings, a complication which is avoided by keeping the incision short. In an attempt to avoid contamination of the operative wound and to in-

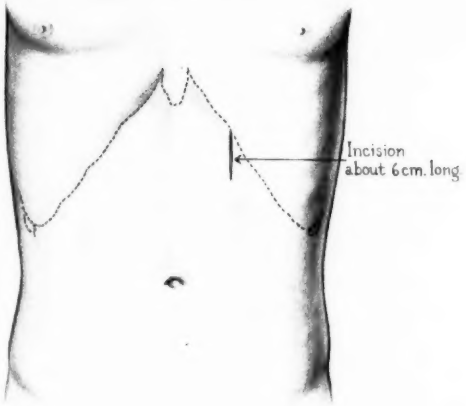


Fig. 1. The operative incision is made through the middle of the left rectus beginning as high as possible at the subcostal margin. It should be kept short. Six centimeters usually is sufficient.

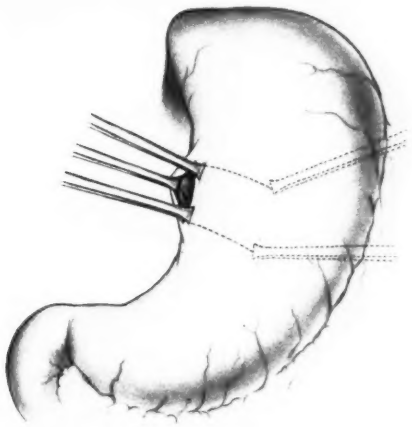


Fig. 2. The first incision is made in the longitudinal diameter near the lesser curvature. An Allis clamp is placed on the lesser curvature side.

sure the fixation of the plastic tube, he brought the latter through a separate stab wound. In so doing, the operative wound is best made in the midline, since a right split rectus incision does not permit of easy access to the body of the stomach without too great length and considerable retraction and manipulation. In any case, a midline incision must be at least 8 to 10 centimeters in length or even longer to permit the necessary manipulation for delivery of sufficient stomach and fixation of the plastic tube in a separate stab wound. This midline incision above the umbilicus is, we believe, the weakest in the entire abdominal wall from the standpoint of immediate healing. It is certainly far simpler to fasten the plastic tube in the operative wound, but this is attended by far more danger of wound infection and subsequent serious complications unless the operative wound is kept short and is made through the strongest portion of the abdominal wall (the rectus muscle).

In our previous report, we also advised inserting the feeding tube through the pylorus, so that the feedings would be delivered into the duodenum for the first few days. The purpose of this procedure was to avoid distention of the stomach until healing was firm. With the present technique, we insert the feeding tube into the stomach only and have found that our former precautions were entirely unnecessary and necessitated more intragastric and intra-abdominal manipulations which tended to produce more surgical shock and infection of the operative wound from contamination by gastric and duodenal contents.

Other factors being equal, we are convinced that the success of this operation depends upon keeping the operative incision short. In the average case there is not a great thickness of subcutaneous fat and an adequate portion of stomach can be delivered through an incision 6 centimeters in length. Such a wound does not require a great deal of separation of muscle fibers and is closed by 3 or 4 sutures. There is little lateral tension on

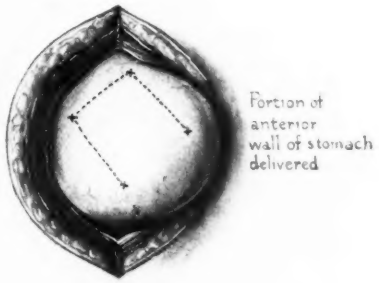
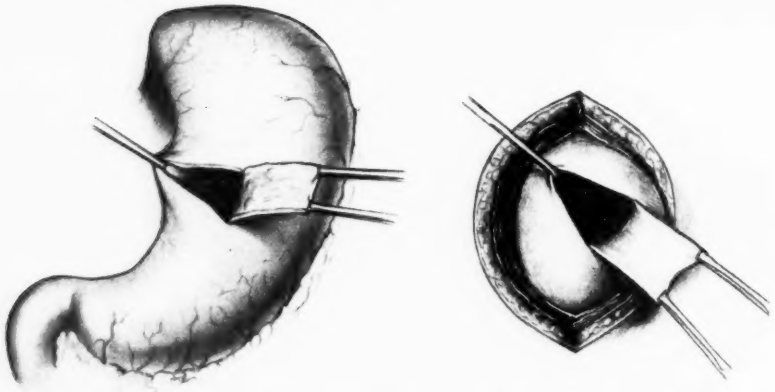


Fig. 3. A portion of the anterior wall of the stomach is delivered through the 6 centimeter incision. The dotted lines show the position and relative size of the intended flap.



Figs. 4 and 4A. The flap has been raised and the Allis clamp at the lesser curvature marks the point of beginning closure.

the wound edges and even though there is slight infection, the fascial edges never separate and permit dislodgment and withdrawal of the plastic tube within the abdominal cavity.

INDICATIONS

Gastrostomy is indicated in all cases of persistent dysphagia in which complete relief cannot be expected within a reasonably short time. In dysphagia of benign origin, such as peptic ulcer of the œsophagus, syphilis, tuberculosis, or in burns following the swallowing of caustics, the indications are too clear to require any special comment. Cardiospasm is almost always amenable to dilatation alone.

Practically all the controversy concerning the indications for gastrostomy is in carcinoma of the œsophagus. We believe gastrostomy to be the best palliative treatment for dysphagia due to malignant stricture of the œsophagus, hypopharynx, or cardia, and that this operation is attended by less risk, discomfort, and mental anxiety than is either bouginage or intubation. We also believe the average length of life to be greater in unselected cases. Bouginage is indicated in patients refusing operation, especially in malignant strictures of the upper half of the œsophagus where the arrested ingesta do not ordinarily cause marked distention or sacculation of the œsophagus.

Gastrostomy puts the malignant stricture at rest and promptly overcomes malnutrition. No further painful or distressing manipulations are required to insure the continuation of proper alimentation. In both bouginage and intubation, the traumatic procedures which surely hasten the extension of the disease, must be repeated every few weeks as long as the patient survives.

Those who favor bouginage or intubation emphasize the disadvantages of gastrostomy such as the operative risk, leakage from the stoma, and the discomfort of constantly wearing the feeding tube. These objections are perfectly valid in operations of the Witzel type, but in the Janeway operation as herein reported, these objections have little or no comparative importance.

We have had no personal experiences with intubation but have used bouginage in 20 cases. The latter procedure is not possible in all instances, depending on the location of the stricture and its morbid anatomy. It is furthermore both distressing and painful in the majority and must be repeated at regular intervals. The same objections apply equally to intubation. In practically all cases in which we have used bouginage, there comes a time after a few weeks or months when this procedure becomes so difficult or is accompanied by so much pain or bleeding that it must be discontinued or done at the risk of immediately fatal consequences. In such cases one is forced to witness death by dehydration or starvation since gastrostomy at this stage is a futile gesture.

If gastrostomy is to be done in cancer of the œsophagus, the earlier the operation is performed the better. It should never be deferred until there is marked loss of weight and strength. If the patient is still able to swallow liquids, he may derive using the stoma for feeding purposes for a time. Its presence causes no discomfort. If length of life is the only consideration, nothing but water

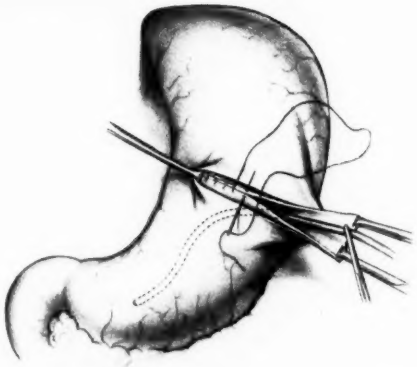


Fig. 5. The feeding tube has been inserted into the stomach. Partial closure of the mucosal layer has been effected.

Fig. 6. The mucosal suture has been completed. The serosal suture is partially completed. Note the clamp fixing the feeding tube to the ends of the mucosal suture.

should be taken by mouth after operation since a portion of swallowed food almost always remains above the stricture to ferment and decompose.

The technique is clearly outlined, we believe, in the accompanying illustrations and will therefore be quite briefly described. If there is even moderate dehydration, the operation had best be deferred for 24 to 48 hours so that the lost fluids may be made up by several hypodermoclyses and by rectal administration. Local anæsthesia is to be preferred. Many patients requiring gastrostomy are in such a state of inanition that general anæsthesia is inadvisable. The operative procedure and intra-abdominal manipulation is so limited that it is seldom that the patient complains of much discomfort.

TECHNIQUE

Under local infiltration alone or combined with a subcostal block, an incision 6 centimeters in length is made through the middle of the left rectus beginning as high as possible at the subcostal margin (Fig. 1). Behind the rectus muscle at this point lie fibers of the transversalis muscle. These are either separated and retracted or partly cut through. A sphincteric action of these muscles was formerly emphasized, but we question if it is of much importance in maintaining continence.

When the abdominal cavity is entered, the anterior wall of the body of the stomach is usually seen lying directly under the wound. In some cases, the stomach may be situated high or the costal margin unusually low and slow manipulation is necessary to stretch the gastrohepatic omentum sufficiently to allow partial delivery of the stomach. It is well to pull the stomach a little to the right so that the plastic tube is placed as far toward the cardia as possible without too much tension. Care should be taken that the plastic tube is constructed from the body of the stomach rather than from the pyloric antrum. In the latter case, leakage and discomfort after feeding are more common. A portion of the anterior wall near the lesser curvature about 8 centimeters in diameter is then delivered through the wound (Fig. 2) and packed about with wet lap sponges.

A rectangular flap, about 3 centimeters long and 2½ centimeters wide with its base toward the greater curvature and its free end at the lesser curvature, is then outlined by Allis clamps (Figs. 2 and 3). The stomach wall is always contracted, particularly in the transverse diameter when delivered and the flap will be found to stretch markedly and become 4 to 5 centimeters in length as the plastic tube is constructed.

The first incision should be made at the free end of the intended flap and parallel to the lesser curvature, and, as the stomach is entered, an additional Allis clamp should be placed in the center of this incision on the lesser curvature side to mark the point of beginning closure (Fig. 3). From the extremities of this incision, two others are made at right angles toward the respective clamps which mark the base of the flap (Figs. 3 and 4). As the flap is freed, the two Allis clamps which mark its tip should be removed and replaced so as to grasp all coats of the stomach wall.

After the ligature of bleeders, a No. 14 French catheter is placed within the stomach only and closure is begun at the clamp which marks the middle of the first incision at the lesser curvature, continuing up the edges of the flap to form a gooseneck tube. We use an interlocked layer of No. 00 chromic to the mucosa and muscular

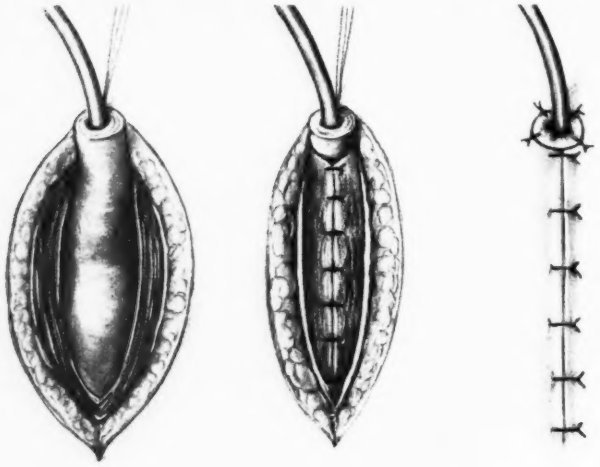


Fig. 7. Showing successive stages of fixation of the plastic tube and closure of the abdominal wound.

coats, and an interlocked Lembert suture of the same material to the serosa (Figs. 5 and 6). When these sutures are completed to the apex of the plastic tube, they are cut long and clamped so as to secure the gooseneck until it is sutured in place. The delivered portion of stomach is then returned to the abdominal cavity, and the plastic tube is placed in the upper angle of the wound (Fig. 7). Closure of the abdominal wound is accomplished in the usual manner not too tightly about the tube, which is attached to the external rectus fascia by two stitches of No. 0 chromic through the serosa only. The plastic tube should protrude slightly above the skin surface (Figs. 8 and 9). It is sutured to the skin by 4 sutures of silk. A vaseline dressing is applied about the catheter, which is made to protrude through all layers of the dressing and adhesive so that the feedings may be given without removal of the dressings.

POSTOPERATIVE CARE

As soon as the patient is returned to the ward, he is given 3 ounces of water through the feeding tube. Following this he is given 3 ounces of milk every 2 hours until the morning after operation when the amount is increased to 4 ounces every 2 hours. The following day 5 ounces every 2 hours and so on, increasing the amount of the feeding to 16 ounces. When the feedings have been increased to about 10 ounces, the interval is lengthened to 3 hours and later to every 4 hours, and finally all feedings are omitted during the nightly period of rest. The caloric value of the feedings is increased by the addition of lactose, eggs, and butter added on successive days beginning about the fifth or sixth day. Orange juice or tomato juice should be added about the same time.

The reason for beginning with small frequent feedings of plain milk is not because of fear of distention of the stomach but rather to avoid gastro-intestinal disturbances which may occur with too copious feedings in patients whose digestive tracts have become unused to digestion. An uncommon postoperative complication is diarrhœa, which may be fatal, the gastro-intestinal tract apparently being unable to retain even fluids. In such cases, the feedings must immediately be reduced to the original quantity (3 ounces) of boiled milk with the addition of small doses of tincture of opium.

The patient may be safely allowed out of bed with a firm abdominal binder on the third to the fifth day, depending chiefly on the pre-operative condition. The position and shortness of the operative incision are such that there is no danger of too early a strain on the incision.

When the skin sutures are removed, the feeding tube is withdrawn and inserted only for feeding purposes. Until the nursing staff is familiar with the after-care of this operation, it is safer to leave the feeding tube in place constantly, the surgeon himself changing it every day or two until about 2 weeks after operation. Inexperienced attendants may misdirect the tube outside the tract and

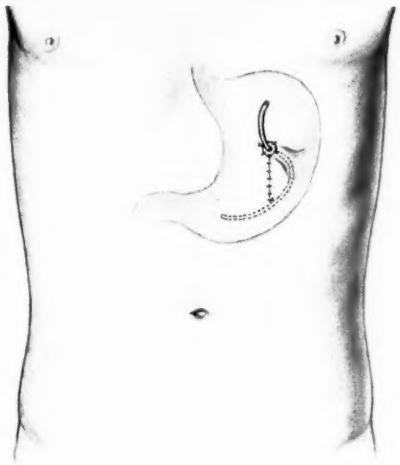


Fig. 8. The completed operation showing the relative position of the operative incision, the stomach, and the plastic tube.

Fig. 9. Healed condition after operation. Note that a small portion of gastric mucosa protrudes above the skin surface.

force the feeding into the peritoneal cavity. After firm healing, there is no danger of this accident. There is no danger of closure of the stoma even if the tube be left out for months. In no case should a larger feeding tube than a No. 16 French catheter be used. Since all feedings must be liquid in any form of gastrostomy, there is no advantage whatever in a larger tube which will only tend to cause leakage by stretching the stoma. At the completion of a feeding when the tube is withdrawn, firm pressure with a gauze sponge over the stoma for a minute, allows the fistula to contract and continence is usually entirely satisfactory and a single gauze sponge is sufficient to cover the stoma under the clothing.

While in the hospital the patient should be taught to insert the tube and feed himself. The caloric value of the daily feedings should be at least 3,000 calories, including the necessary vitamins. Many intelligent patients seem to derive a great deal of interest in the make up and calculation of the feedings. For the guidance of the average patient, we furnish a mimeographed copy of the following instructions.

GASTROSTOMY FEEDING

Patient's name: Address:

Hours of feeding	Milk	Milk sugar	Butter (melted)	Fresh eggs (raw)
6 a.m.	2⅜ cups or 17 oz.	3 scant tbsp.	1 tsp.	1
8 a.m.	(8 oz. tomato juice)			
10 a.m.	17 oz.	3 scant tbsp.	1½ tsp.	2
2 p.m.	17 oz.	3 scant tbsp.	1½ tsp.	1
6 p.m.	17 oz.	3 scant tbsp.	1½ tsp.	1
10 p.m.	17 oz.	3 scant tbsp.	1½ tsp.	2

At 10 a.m. 1 dram (1 tsp.) iron and ammonium citrate.

1. Insert tube only for feedings.
2. Make up each feeding fresh. Heat slightly before using.
3. Take feeding slowly—allow at least 10 minutes for each feeding.
4. Rest 10 minutes after each feeding.
5. Clean feeding tube with water after each feeding—do not boil.
6. Obtain from drug store:
   1. One No. 14 French catheter.
   2. "Asepto" syringe with a tip to fit catheter.
   3. Large can of Lactose (milk sugar).
   4. Iron and ammonium citrate, ounces 8, and take 1 teaspoonful in the 10 a.m. feeding.
   5. One 8 ounce measuring cup.
7. If constipated, take one ounce of castor oil in the last feeding at night.
8. Take nothing by mouth except water. This may be taken in small amounts if it does not cause vomiting.
9. If stomach distress and nausea follow the feedings, the milk content should be reduced to 12 ounces for 2 or 3 feedings.
10. Any unusual symptoms or difficulties should be reported to the hospital.

POSTOPERATIVE MORTALITY

In our series of 52 gastrostomies done by the present technique there have been 3 postoperative deaths (5.8 per cent), which we believe to have been incidental and due to the disease (carcinoma

of the œsophagus) rather than to complications resulting from the operative procedure. One patient had an uneventful recovery with primary healing until the ninth postoperative day when he suddenly fell dead while walking about the ward in apparently good condition—probably a cardiac death. The second was admitted with complete dysphagia and symptoms of mediastinitis. X-ray examination showed the presence of a broncho-œsophageal fistula and bronchopneumonia. After 48 hours, during which time fluids were forced by hypodermoclysis and proctoclysis, his condition improved sufficiently so that gastrostomy was thought indicated, since the patient could swallow not even water. The postoperative course was fairly satisfactory for 12 days. He died on the fourteenth postoperative day and autopsy showed death to have been due to broncho-œsophageal fistula and bronchopneumonia. A third patient died on the fourth postoperative day from œsophageal hæmorrhage probably from perforation of the aorta by disease.

Carcinoma of the œsophagus is a lethal disease and gastrostomy is not done in many cases until such terminal complications as perforation of the growth into a large vessel or bronchus are imminent. Such complications are apt to occur during the postoperative period and therefore gastrostomy, if done for cancer of the œsophagus, will always be followed by a certain unavoidable percentage of postoperative deaths. Good statistics will, therefore, depend partly on chance and on as early operation as is possible.

The postoperative mortality in gastrostomy varies from 6 to 20 per cent as published by various authors. We believe that the lower figure is possible with the Janeway technique and the advocacy of operation as soon as the diagnosis is made.

SUMMARY

The advantages and technique of an improved original Janeway gastrostomy are described. This operation differs from that already published by Quick and one of us, in that the procedure is done through a single 6 centimeter incision through the middle of the left rectus just below the costal margin. The fistulous tract from the stomach to the skin is formed by a plastic tube constructed from stomach wall. By this technique we have performed gastrostomy in 52 cases with a postoperative mortality of 5.8 per cent.

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FROM THE CLINIC OF DR. PHILIP LEWIN, MICHAEL REESE HOSPITAL[1]

THE GALEAZZI TREATMENT OF SCOLIOSIS

PHILIP LEWIN, M.D., F.A.C.S., CHICAGO

SCOLIOSIS is one of the oldest conditions described in medical literature. Hippocrates gave the generic term "scoliosis" to any twisted spine. An extensive literature, much of which is repetition, has been accumulated on the subject. The outstanding contributions have been made by such men as Schulthess, Wullstein, Lovett, Brackett, Abbott, Freiberg, Kleinberg, Hibbs, Steindler, Feiss, Calvé, Buchman, Brewster, Risser, and Galeazzi.

The spine, a flexible weight bearing column made of segments and already curved in one plane (anteroposterior), will not yield in another plane (lateral) without twisting. In this twist the vertebræ must turn away from the greatest weight and pressure, that is, toward the convexity.

The etiology of scoliosis involves chiefly such factors as: (1) heredity; (2) congenital anomalies of the spine; (3) pathological conditions of the vertebræ; (4) nutritional changes; (5) infections; (6) epiphyseal changes; (7) muscle disbalance; and (8) paralytic conditions. There is a large group of cases included under the term "idiopathic" scoliosis.

Hibbs believed that in a great many more cases than were recognized, the condition was due to infantile paralysis. Buchman believes that many are due to vertebral epiphysitis. Jansen attaches importance to irregularities in the attachments of the diaphragm.

Ferguson has been impressed by the apparently reciprocal relation between rotation and wedging of the vertebral body. With a curve of given degree in a given area of the spine, he finds a definite amount of rotation, unless wedging is present. With wedging there will be less rotation. Wedging appears to decrease the need for rotation.

In 1844, Bigelow advanced the principle that torsion rotation is illustrated by bending a blade of grass or a flat flexible stick in the direction of its width. The center rotates on its longitudinal axis to bend flatwise in the direction of its thickness. Likewise, the spine laterally flexed, turns on its vertical axis, to yield in its shortest, or anteroposterior, diameter. This statement, according to Smith, implies: (1) that there is a continuity of substance in the spine; (2) that the spine is flat; (3) that the plane of flatness is in the frontal plane; and (4) that rotation is a concomitant element of lateral flexion.

When he began his investigations of the subject of scoliosis, Carey found that there was very little accurate anatomical and physiological knowledge concerning the mechanism of production of structural scoliosis. By two types of experimentation and investigation, he has been able to make some interesting and important observations on the subject. The first method included a series of experimental amputations, selective muscle and nerve excisions, tail fixations, undernutrition experiments in young animals, and observations on the dynamics of the histogenesis of muscles, bones, and joints. The second method was the construction of a working model of the anatomical and physiological relations of muscle and bone levers of the normal human back. By this means, results of experimental muscular imbalance registered at once on his spinal indicator, whereas by animal experiments he was forced to wait months, and sometimes over 2 years, for the same change to occur. This model is a most ingenious piece of mechanical construction. It enables one to demonstrate the greatest variety of structural mechanical changes and to visualize the normal and

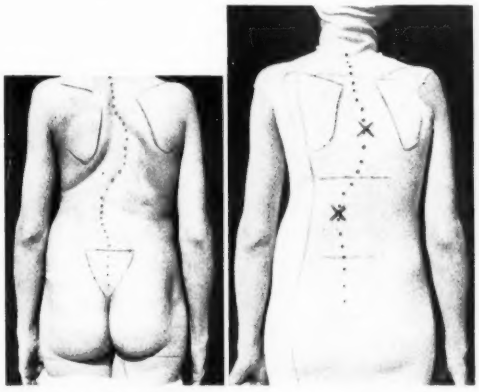

Fig. 1, left. Skin marks.

Fig. 2. Stockinette with marks indicating spinous processes and scapulæ. *X* and *X* mark centers of thoracic and lumbar curves.

[1]And from the Northwestern University Medical School Dispensary

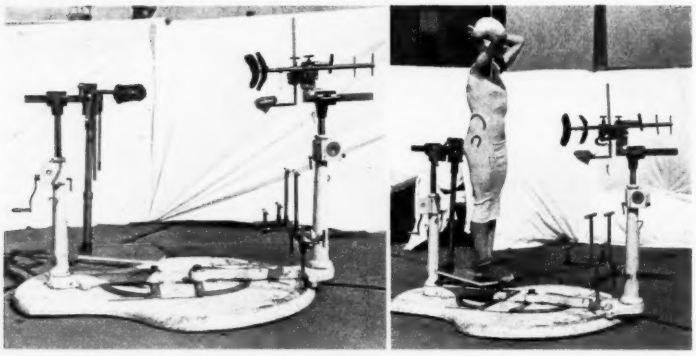

Fig. 3. Galeazzi apparatus showing two end fixation mechanisms for immobilizing pelvic and shoulder girdles and two floor nuts. (Under worm gear apparatus not shown.)
Fig. 4. Patient standing on platform preparatory to fixation of pelvic and shoulder girdles. Note outline of great trochanter and crest of ilium.

abnormal dynamic equilibrium of the musculature of the body as a whole.

Carey believes that imbalanced action of bilateral antagonistic musculature resulting from undernutrition or malnutrition during the first decade of life will explain many cases of idiopathic scoliosis. He found that there are numerous possible combinations of muscular imbalance. With only 13 pairs of spinal muscles there are more than 67 million possible combinations of muscular imbalance resolved by the mathematical formula (2^n I). There are 144 muscles directly attached to the movable spine. It is impossible to conceive the results of multiplying out to the 144th power.

When I told Dr. Steindler in 1925 that I was going to Europe, he advised me to visit Galeazzi at Milan. At Manchester, England, I met Platt who spoke very favorably of the method. Then Delitala of Venice recommended it. In 1929, I visited Galeazzi again. In May, 1931, I made my third trip. In 1928, I demonstrated the method before The Clinical Orthopedic Society in Chicago.

Through the efforts of Dr. D. H. Levinthal, the Ruth Lodge of Chicago purchased the apparatus

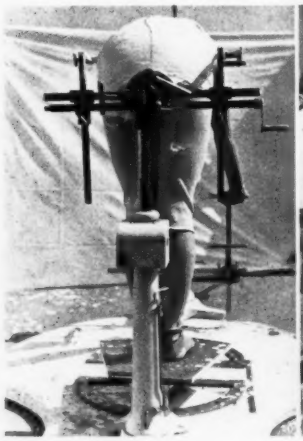

Fig. 5.

Fig. 5. Rear view of patient in apparatus with pelvic girdle fixation.

Fig. 6.

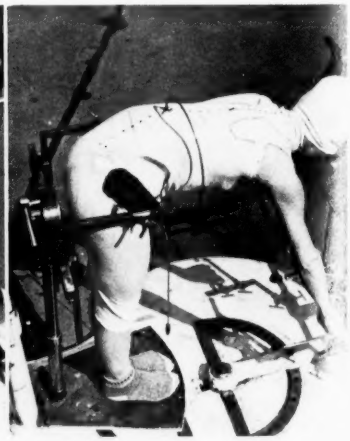

Fig. 6.

Fig. 6. "Centering" of thoracic and lumbar curves over nuts on floor of apparatus by means of plumb.

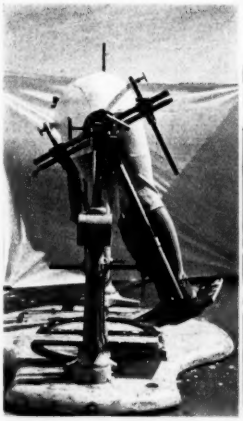

Fig. 7. Rear view showing deflexion of lower back.

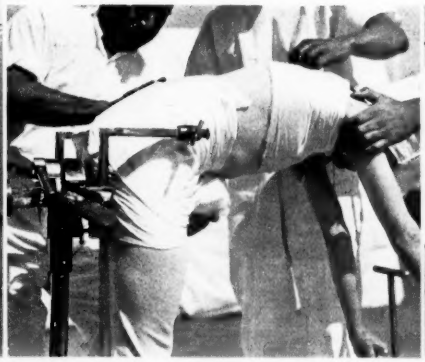

Fig. 8. Sheet wadding applied to pelvic and shoulder girdles.

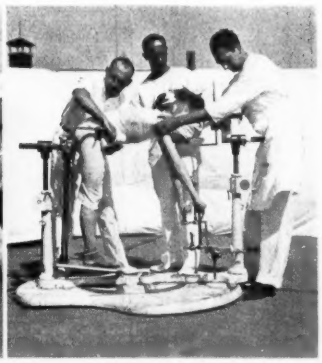

Fig. 9. Application of pelvic and shoulder plaster girdles.

at a cost of one thousand dollars and presented it in 1930 to Michael Reese Hospital. I began using the apparatus in September, 1930. Dr. Levinthal and I have worked with the machine individually and together.

I wish to outline the general considerations of a method of treating the difficult problem of scoliosis which has been found to be highly successful in the originator's hands. This is a preliminary report based upon observation in Galeazzi's clinic in Milan in 1925, 1929, and 1931, and in my own clinic.

The method may be described as follows: The patient is placed under an intensive preparatory mobilizing treatment for a long period, varying with the degree of rigidity of the spine. Special apparatus and exercises are used in this preparatory treatment. Accurate tracings are made by the Schulthess method as well as plaster-of-paris shells and models. Then one proceeds to correct the deformity by means of the apparatus herewith illustrated. There are two independent units, one which secures the shoulder girdle and the other the pelvic girdle. The patient is placed on a raised platform within the apparatus, with the trunk horizontal and hips and arms flexed so that the spinal column is suspended from two end buttresses; that is, he assumes the position

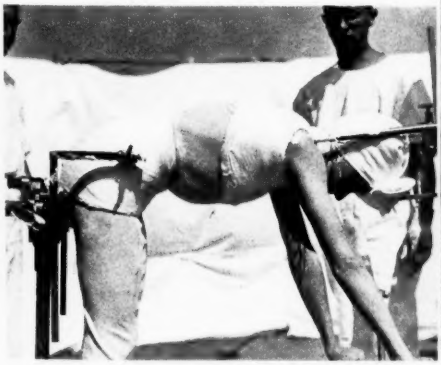

Fig. 10. Pelvic and shoulder girdles complete. Ready for deflexion and derotation.

Fig. 11. Lower back deflexed and derotated.

Fig. 12. Cast almost complete, showing traction bands still *in situ*.

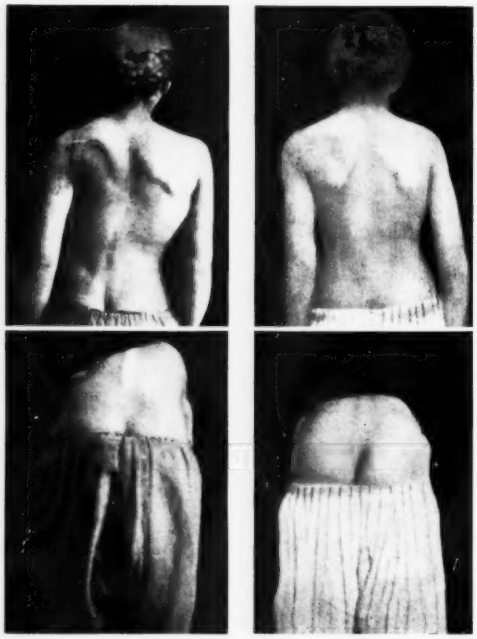

Fig. 13. A patient with rigid structural scoliosis corrected in Galeazzi apparatus. (Courtesy of Professor Galeazzi.)

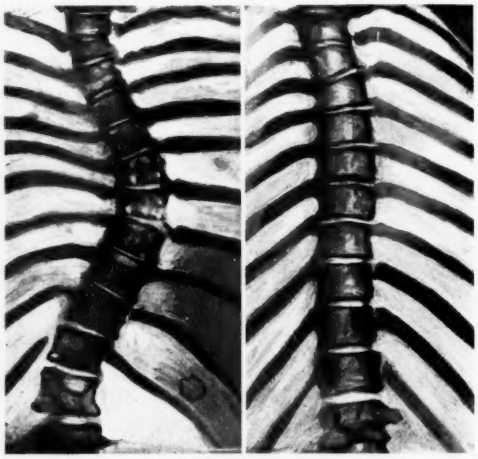

Fig. 14. Roentgenograms of patient with rigid structural scoliosis corrected in Galeazzi apparatus. See Figure 13. (Courtesy of Professor Galeazzi.)

of a quadruped. By varying the distance between the two end units and their relative heights above the ground, it is possible to place the spine in the most favorable position for correction. When this position has been obtained, the two end units are secured, so that the apices of the thoracic and lumbar curves correspond with the centers of the rotatory mechanism, which are indicated by two nuts on the floor of the apparatus. A plumb line is used for this purpose.

The apparatus permits independent rotatory movement of the two end units around a vertical axis, which accomplishes lateral deflexion of the spine. It also allows rotatory movements around the longitudinal axis of the spine, producing derotation and detorsion.

The scoliotic spinal column is secured at its two ends by the application of two plaster-of-paris sections, including the pelvic and shoulder girdles. By means of a three tailed bandage applied over the apex of each curve and held by an assistant so as to act as fulcrums, one slowly begins to correct by means of deflexion and derotation against the fixed shoulder and pelvic girdle sections. These are then united by the third plaster-of-paris section. The principle is analogous to the correction of a club foot by the application of three plaster cuffs.

The cast extends from points high on the shoulders to others below the greater trochanters. Windows are cut out over the concavities of the curves. When the cast is complete, the patient stands in a flexed position and walks with his body flexed toward the convexity in a manner similar to, but not quite so severe as in, the Abbott method. These casts are changed every 3 months. The total duration of the cast period is from 18 to 36 months.

The chief virtues of the treatment are in correction by deflexion and derotation rather than by means of direct force. The key to the correctability of the spine lies in a long preparatory mobilizing treatment. Galeazzi uses a mobilizer similar to the apparatus used for correction.

Galeazzi has obtained correction even in cases of rigid structural scoliosis. He has used the method in the treatment of several hundred severe, rigid cases of scoliosis with excellent results, as demonstrated by roentgenograms which have disclosed definite, and he believes permanent correction of the vertebral torsion. He uses celluloid jackets to maintain correction.

It is not my purpose to compare various methods of treatment of scoliosis. I merely wish to describe one method. I have used the Abbott method under Ridlon, Porter, and Calot. I have used the original Hibbs traction method.

have had a limited but very favorable experience with the Risser method, which probably is the best in America, or possibly, the world today. It has the advantage that it is simple and not expensive.

I have made some modifications in the technique since it was described in an article which Galeazzi wrote at my request, and which appeared in the *Journal of Bone and Joint Surgery* for January, 1929.

The disadvantages of the method include: (1) the cost of the apparatus; (2) the long period of preparation by means of special apparatus necessary to accomplish good results; (3) the difficult technique of application; and (4) the long after treatment.

The illustrations were made at the same time a moving picture film was prepared to illustrate Galeazzi's method. The subject was a patient of Dr. Levinthal.

SUMMARY

After an intensive preparatory mobilization period, the patient is placed on a small elevated platform and the pelvis is secured firmly. He bends at the hips and shoulders with hands supported on uprights and forehead on a rest, i.e., he assumes the position of a quadruped. His pelvic and shoulder girdles are secured by sections of plaster of Paris. His torso is then deflexed and derotated. The two sections are united by a third.

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OLD TRAUMATIC DISLOCATION OF THE HIP

With Special Reference to the Operative Treatment

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From the Division of Orthopedic Surgery, Department of Surgery, Peiping Union Medical College

SIXTEEN cases of old traumatic dislocation of the hip have been treated at the Peiping Union Medical College during the past 10 years. The time of postoperative observation has extended from 6 months to 9 years, with an average of 2 years for all cases. Since this condition is seen rarely in most clinics, a review of the subject and a presentation of cases seems appropriate.

PATHOLOGICAL ANATOMY

In order to understand fully the pathological anatomy of old dislocations of the hip (Fig. 1), it is necessary to discuss the changes which occur during as well as after the original trauma.

Posterior dislocations. The position most favorable for the posterior type of dislocation is one of flexion, adduction, and internal rotation. Ordinarily the capsule is torn through in the postero-inferior portion. As the head of the femur passes backward and upward it may tear one or more of the small rotator muscles. The quadratus femoris lies directly in the path of the head during dislocation, hence it is injured very frequently. The obturator externus, obturator internus, the gemelli, and even the pyriformis may be injured similarly in severe cases. Occasionally the head may push its way between the obturator internus and the pyriformis, or between the pyriformis and gluteus minimus, without trauma to these muscles. If the dislocation occurs below the tendon of the obturator internus, the head then passes laterally and upward so that the tendon lies between the neck of the femur and the ilium (dislocation below the tendon—Bigelow—Fig. 2). In the same way the tendon of the pyriformis may be wound around medial to the neck of the femur (Fig. 3). An intact condition of the Y-ligament is responsible for producing the characteristic position of the thigh after dislocation, i.e., flexion, adduction, and internal rotation. In rare instances the Y-ligament may be ruptured completely, with the result that the thigh is then held in a position of flexion, abduction, and external rotation—the so called everted posterior dislocation.

Contractures of the pelvic femoral muscles soon take place in the untreated case. As time goes on a new capsule of scar tissue forms around the head of the femur fastening it securely to the side of the pelvis. Within 4 weeks' time ligamentous shreds, fat, and new connective tissue fill the acetabulum. This mass of tissue adheres firmly to the cartilage so that, after 6 weeks, sharp dissection is necessary for its removal. As early as 1893 Volkmann recognized these changes following experimental dislocations in rabbits and dogs. He found that after 3½ weeks new connective tissue adhered firmly to the cartilage and that after 8 or 10 weeks the joint was filled with a hard fibrous mass which in itself prevented reduction. One of the writers (L. J. M.) repeated these experiments with essentially the same findings.[1] Similar clinical observations have been made by surgeons during the operative treatment of congenital dislocations. In several instances redislocation of the hip occurred shortly after open reduction and, upon re-operation 3 to 4 weeks later, the acetabula were filled completely with adherent soft tissues.

Changes in the head of the femur occur almost routinely as a result of the original trauma or the pressure forces which follow dislocation (Fig. 4A). If a piece of the femoral head has been crushed or broken off during the dislocation the late findings are those of roughening and partial disappearance of the cartilage—changes simulating advanced arthritis. In the very old cases, the head may be flattened or roughened because of weight bearing in a deformed position.

Anterior dislocations. In the anterior group of dislocations, displacement of the head of the femur most commonly is against the obturator foramen, with abduction, external rotation, moderate flexion, and apparent lengthening of the thigh. The head of the bone tears through the capsule in the antero-inferior portion and lies on the obturator membrane where it is partly surrounded by the torn fibers of the obturator externus muscle. The ligamentum teres may be stretched or completely torn through. The small external rotator muscles of the hip are drawn over the posterior edge of the acetabulum. In all of the anterior dislocations whether obturator, pubic, or perineal in type, the acetabulum fills with a mass of scar tissue just as it does in the posterior variety. Complete tearing of the Y-ligament also is very unusual in the anterior type. In late cases

[1] Unreported work.

locations of either anterior or posterior type an unusual amount of new bone may form around the displaced head (Fig. 4B).

OPERATIVE TREATMENT

Preliminary skeletal traction. In late posterior dislocations traction as a preliminary step before reduction by either the closed or open methods is a procedure which cannot be overemphasized. By this means the contracted structures are stretched gradually until the head of the femur has been pulled down to the level of the acetabulum (Figs. 5A and 5B). As a result the amount of force necessary to effect reduction and the local trauma produced at the time of operation becomes much less. In cases of more than 1 month's duration the writers advocate skeletal traction with a Steinmann pin through the lower end of the femur. (For technique see Case 1.)

Closed reduction. Most traumatic dislocations of the hip may be replaced by the closed method if the duration is less than 4 weeks. Following this period of time the difficulties of reduction gradually increase so that, after 2 months, forceful maneuvers are apt to cause fractures of the upper portion of the femur. Consequently, if closed reduction is attempted between the fourth and eighth weeks, it must be performed with great caution and, if unsuccessful, open arthrotomy should be employed. Careful study of stereoscopic roentgenograms will help to determine the advisability of late manipulation. Such study is important since the original trauma may have caused crushing injuries to the head of the femur, and any great external force will only effect more damage. A description of the standard technique of closed reduction is not within the scope of this paper.

Open reduction. Studies by Bigelow, Malgaigne, Allis, and others of the pathological anatomy of dislocations of the hip led surgeons to a knowledge of the possibilities of open operation. The first arthrotomy to effect reduction of an old traumatic dislocation is usually accredited to Polaillon (1882). Since that time successful operations have been surprisingly few, both because of the rarity of the condition and because of the technical difficulties involved. Buchanan collected from the literature, up to 1920, 49 cases reduced successfully by arthrotomy and added one of his own. The largest individual series belongs to Dollinger (3), who in 1925 reported results obtained by arthrotomy in 29 cases of inveterate traumatic luxations. In his group twenty-one hips were replaced completely. Difficulties in reduction necessitated resection of the femoral head in 7 cases and osteotomy in 1 case.

Two methods of approach have been used for old posterior dislocations, namely, the posterior one of Langenbeck and Hoffa, and the anterior one of Smith-Petersen. Dollinger prefers the posterior method, which is thus briefly described. An incision is made from the postero-inferior spine of the ilium to the base of the greater trochanter, or on down to the insertion of the gluteus maximus. The fibers of the gluteus maximus muscle are split longitudinally, exposing the secondary capsule which surrounds the head of the femur and holds it to the pelvis. The secondary capsule is opened and by forceful internal rotation the head and neck of the femur are swung anteriorly and away from the acetabulum. In the ordinary dorsal dislocation the scarred obturator internus, gemelli, and pyriformis muscles are now exposed. These muscles may lie between the neck of the femur and the pelvis and stretch across the upper and outer aspect of the acetabulum. Myotomy of these muscles is usually necessary, to give full access to the socket of the hip joint. After the removal of all of the scar tissue from the acetabulum, the head of the femur is replaced by circumduction and traction.

Dollinger also uses the same approach for anterior dislocations (obturator) of the hip. In this type, access to the acetabulum is blocked by the greater trochanter and the muscles already mentioned, consequently resection of scar tissue, myotomy, and inward rotation of the femur are necessary.

The anterior route was used in all except one of the cases reported in this paper. The incision is started at the middle of the iliac crest, continued forward until the anterosuperior spine is reached, and extended downward along the anterior border of the tensor fasciæ to below the level of the symphysis pubis. After the periosteal origins of the gluteus minimus and part of the gluteus medius have been stripped loose, the upper edge of the acetabulum comes to view. Further dissection is made between the sartorius and tensor fasciæ until the rectus femoris and iliopsoas muscles are seen. Myotomy of these muscles and resection of scar tissue allow complete exposure of the socket. The safest approach to the head is made by subperiosteal dissection along the upper end of the shaft and the neck until the secondary capsule is opened widely. The thigh is now rotated externally, causing the head of the femur to point laterally. This tightens the scar tissue which stretches between the neck of the femur and the pelvis. These cicatricial bands are severed transversely. Reduction of the hip may be accomplished by traction and manipulation.

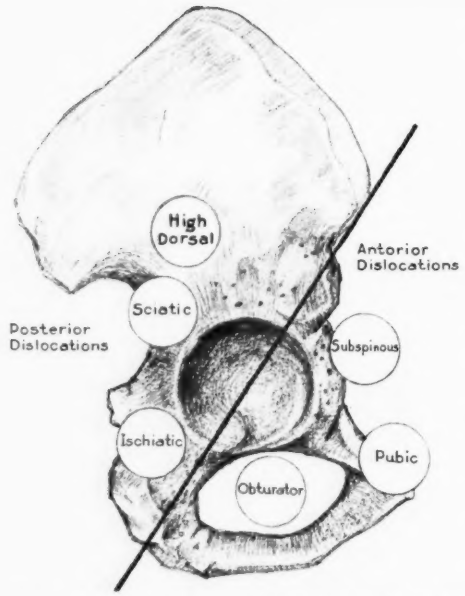

Fig. 1. Schematic drawing which illustrates the various positions of the head of the femur in dislocations of the hip. According to Allis' classification, a line drawn from the anterosuperior spine of the ilium through the center of the acetabulum divides such dislocations into two main groups. All anterior to this line are designated as anterior dislocations (obturator, pubic, subspinous, and perineal); and all posterior to this line are designated as posterior dislocations (ischiatic, sciatic, and high dorsal). (Redrawn from Wilson and Cochrane.)

For obturator dislocations the anterior, or if occasion demands, the combined anterior and median approaches offer good exposure. Recently the writers used a modification of the anterior approach for an obturator dislocation of 2 years' duration (Fig. 6). The incision was started at the junction of the anterior and medial thirds of the crest of the ilium, continued forward to the anterosuperior spine, and then extended downward along the medial edge of the sartorius muscle to the apex of Scarpa's triangle. The gluteus minimus, rectus femoris, and sartorius muscles were retracted laterally. This allowed ready access to the acetabulum. The scar tissue was removed from the socket following which the upper edge of the head of the femur was exposed. It was necessary to chisel away a shelf of new bone which had formed at the junction of the obturator foramen and the acetabulum. Further dissection allowed exposure of the capsule of scar tissue which surrounded the neck. This was cut transversely. Forceful adduction and external rotation brought the head into full view. Following its long period of contact with the margins of the obturator foramen the head had become somewhat pear-shaped and roughened, with hypertrophic flanges of bone at the junction with the neck. Since the acetabulum also was roughened it was believed that if the head were returned to the socket in this condition an arthritic hip joint would result. In the hope of overcoming this almost inevitable sequela, the head was chiseled down to one-third its former size and then maneuvered into the acetabulum. In a case of 3 months' duration Dr. Steindler used both the median and anterior approaches. The median incision (Ludloff) was made along the inner border of the adductor magnus. The head was approached by dissection between the adductor longus and adductor magnus muscles. Myotomy of these muscles was necessary to allow good exposure of the scarred mass surrounding the head. The secondary capsule was split and the thigh was abducted and externally rotated, making the whole head and neck visible. Exposure of the acetabulum by this route was extremely difficult. A second approach, which was that of Smith-Petersen, was then made. The scar tissue was removed from the socket and the hip was manipulated into normal position.

While complete reduction by open arthrotomy is the goal sought in all cases of old dislocation, the surgeon may be forced to accept certain alternative procedures such as the "shelving" operation, resection of bone, arthrodesis, or, in exceptional instances, he may be content with simple osteotomy to correct the deformity.

"Shelving" operation (Koenig, 1891, 9; Albee, 1915, 1). The shelving operation consists in the formation of an efficient bony roof over the displaced head of the femur. The shelf is made by turning down plates of bone from the outer surface of the ilium for the purpose of affording stability and preventing pain. Henderson reported a case in which, during arthrotomy, it was impossible to bring the head of the femur far enough forward and downward to replace it in the acetabulum. Hence, with a Murphy reamer such as is used for arthroplasty, a new acetabulum was made a little higher than the old one. In addition flaps of bone were turned down over the superior surface of the head. Four months later roentgenograms showed an excellent new acetabulum with a well formed shelf. Motion was fair with flexion 140–150 degrees. He expected a stable hip as an end-result. Shortening in this case was about 3 centimeters previous to operation it had been 8 centimeters.

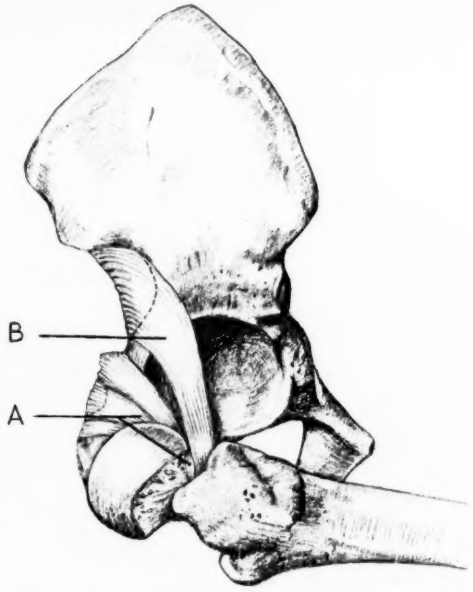

Fig. 2. Sketch illustrating the mechanism of posterior dislocation below the tendon of the obturator internus. The femur is in a position of flexion, internal rotation, and adduction. In this type the head of the femur breaks through the posterior inferior portion of the capsule below the tendon of the obturator internus, *A*. Note that the head in rotating upward, passes lateral to this tendon. The head may also pass lateral to the tendon of the pyriformis, *B*. In this event both tendons, *A* and *B*, are wound around the neck of the femur and therefore lie between the neck of the femur and the ilium.

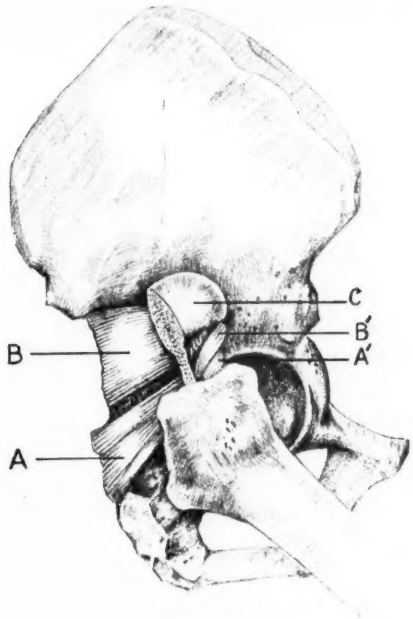

Fig. 3. Drawing to represent a further stage of dislocation into the high dorsal position. Part of the head and neck of the femur, *C*, has been cut away so that a better view of the tendons may be obtained. The obturator internus, *A* and *A′*, and pyriformis tendons, *B* and *B′*, pass between the neck of the femur and the pelvis, and wind anteriorly around the neck, to reach their insertions into the region of the great trochanter.

Resection (Hoffa). Dollinger believes that resection of a portion of the head of the femur, or even of the whole head, neck, and great trochanter, may be done if reduction is extremely difficult, or if pressure symptoms are present in the distribution of the sciatic nerve. Following this procedure the upper end of the femur is placed in the acetabulum and partial fibrous ankylosis with good position of the hip is the usual result.

Fusion. Arthrodesis of the hip may be the operation of choice in very late cases, especially when the musculature is atrophic and contracted. It may also be indicated in cases showing a large amount of new bone at the site of displacement. This procedure should result in a permanent relief from pain, deformity and instability of the hip.

Osteotomy. Simple osteotomy for the correction of deformity may be advisable in patients who are old or weakened and who would be unable to withstand the rigors of a more severe operation. Again osteotomy may find an indication in those cases wherein roentgenograms show that complete reduction would be technically impossible. Figure 4 shows a case of 1 year's duration in which an unusual amount of bone had formed in the torn soft tissues. In this instance osseous bridges actually connected the region of the acetabulum with the newly formed capsular structures surrounding the dislocated head of the femur. The femur was almost completely ankylosed in a position of 110 degrees flexion, 20 degrees abduction, and 20 degrees external rotation. Because of the firm and painless fixation of the upper end of the femur, a subtrochanteric osteotomy was proposed but the patient refused treatment.

It is also suggested that the Lorenz-Baeyer (8) bifurcation operation may find an occasional application. This method has recently received favorable comment by Hackenbroch and others in cases of irreducible congenital dislocations of the hip. This operation aids in the correction of instability, pain, and limp.

Fig. 4A. Traumatic dislocation of 10 years' duration. (Patient 35 years of age; untreated.) Note well shaped secondary socket which has formed on ilium posterior and superior to primary acetabulum (arrows, the rim of acetabulum). Head of femur appears flattened and roughened.

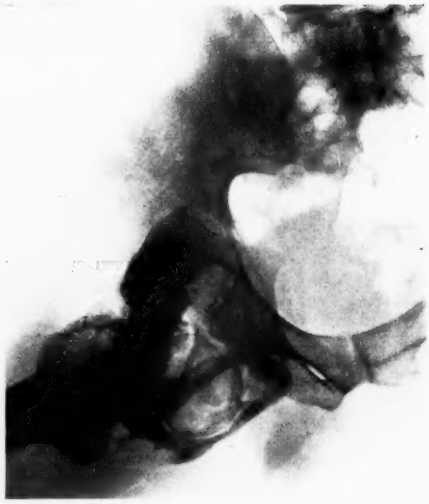

Fig. 4B. Roentgenogram of an everted ischiatic dislocation of 2 years' duration. Note the extensive calcification of the capsular structures which surround the head. Approximately 25 degrees of flexion motion was present in the hip.

Arthroplasty. Arthroplasty may be indicated if, during open arthrotomy, the femoral head is seen to be roughened and arthritic and fibrous ankylosis seems probable or if, after successful open reduction, the hip continues to show marked pain and limitation of motion in the presence of good musculature.

From the statistical table it may be seen that complete reduction was accomplished in every case. Some of the operations were necessarily prolonged and severe but on the whole the results were very encouraging. Follow-up records show that the results were excellent in 8 cases, good in 1 case, fair in 4 cases, and poor in 2 cases. In an evaluation of the success of the treatment in this series it should be repeated that the duration of the dislocations varied from 3 weeks to 4 years, with an average period of 7.7 months in all cases studied.

In order to emphasize interesting observations made during the surgical management of these cases the following records have been selected for detailed report. The first case illustrates the value of skeletal traction as a preliminary step to open arthrotomy for old posterior dislocations. The most serious complications of arthrotomy were the development of secondary infection (2 cases) and injury to the sciatic nerve (1 case). The danger of fracture during late manipulation is shown in Case 4. Another history illustrates the development of marked hypertrophic arthritis several years after open arthrotomy. It was interesting to note that 80 per cent of the cases showed similar changes in follow-up roentgenograms. Usually the arthritis was of mild nature and caused pain only upon overuse of the hip. Case 6 is added because of the very unusual etiology. In this instance a rifle bullet passed through the medial portion of the head, and caused a fracture of the posterosuperior rim of the acetabulum. It is believed that the combination of capsular tear and fracture allowed subsequent muscular pull to produce the dislocation. Fortunately, infection did not follow so the dislocation was treated in the usual manner. The last 2 cases (shown only by photographs and roentgenograms, Figs. 11 and 12) are illustrative of excellent results which are obtained following open reduction.

THE VALUE OF SKELETAL TRACTION BEFORE OPEN REDUCTION

CASE 1. A Chinese male, aged 35 years, was first seen April 2, 1931. The entrance complaint was pain and deformity of the right hip of 80 days' duration. The general physical examination and laboratory tests of blood and urine gave normal findings. The right thigh was held in a typical position of posterior dislocation—flexion (45 degrees), adduction (30 degrees), and internal rotation

Fig. 5A. Roentgenogram showing an old traumatic dislocation of the left hip (4 years). The head of the femur is in the high dorsal position.

The great trochanter was 2.5 centimeters above Rose Nelaton's line and the measurements of Bryant's triangle were compatible with dislocation. There was approximately 4 centimeters of actual shortening. The roentgenographic report confirmed the clinical impression; in addition there was a displaced fracture of the postero-inferior portion of the acetabulum.

Fig. 5B. This roentgenogram (same case shown in Fig. 5A) was taken 3 weeks after the application of skeletal traction to the lower end of the femur. The head of the femur might appear to be within the acetabulum, but it actually lies directly posterior to the socket. The dark shadow represents the upper end of the Thomas ring.

On April 10, 1931, a Steinmann pin was inserted through the lower end of the right femur. A Thomas splint was applied and traction was maintained for 10 days. The traction was started at 5 pounds and increased gradually up

Fig. 6. An obturator dislocation of 2 years' duration. Note the extensive formation of new bone in the obturator foramen. This hip was reduced by open arthrotomy through a modified Smith-Petersen incision.

Fig. 7. Roentgenogram of an old traumatic dislocation which became infected following open reduction. This picture represents the late healing stage of suppurative arthritis.

Fig. 8A. Roentgenogram showing an old traumatic dislocation of the obturator variety (duration 2 years). Note that the head is completely displaced through the foramen. Also note the calcified material which surrounds the head—an imitation of the primary acetabulum.

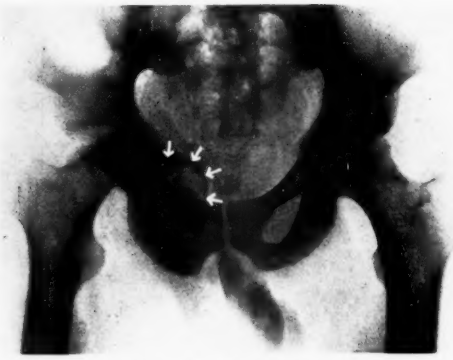

Fig. 8B. Roentgenogram from the same case shown in Figure 8A following closed reduction. A portion of the head of the femur remained within the secondary socket. The intact portion of the head was placed successfully in the acetabulum.

to 20 pounds. At the end of this period of time the head of the femur had been pulled down to the level of the acetabulum. On April 20, 1931, open reduction was performed with the aid of spinal anæsthesia. A Smith-Petersen incision was used. Upon dissection toward the hip joint a dense scarred mass of iliopsoas muscle was found stretched over the inferior half of the acetabulum. This was cut through and the rim of the socket was exposed. The acetabulum was filled with remnants of capsule, fat, and newly formed connective tissue. After this was removed, intact cartilage was seen. The head and neck of the femur were then exposed by an incision through the secondary capsule. Forceful external rotation stretched taut the scar tissue bands of the obturator internus and pyriformis tendons since both of these structures were wound around the neck of the femur and therefore lay between the posterior edge of the acetabulum and the neck of the femur. Following tenotomy of these tendons and further cutting of the scar tissue, the head of the femur was reduced rather easily. The relative ease of reduction was accredited to the

Fig. 9A. Roentgenogram of an old sciatic dislocation (12 months' duration) before operation. Note the fracture of the posterior rim of the acetabulum.

Fig. 9B. Roentgenogram of the hips hown in Fig. 2 years and 9 months after successful open reduct Note the presence of marked hypertrophic arthritis. cellent function of the hip was present.

Fig. 10A. Pre-operative roentgenogram of an old gunshot fracture-dislocation of the hip (80 days). Apparently the bullet passed through the head of the femur and fractured the posterosuperior rim of the acetabulum.

stretching and relaxation of the soft structures which followed preliminary skeletal traction. The wound was closed in the usual manner and a long leg hip spica cast was applied with the thigh in 25 degrees' abduction.

The patient ran an uneventful postoperative course. The cast was removed 2 weeks after operation. Physiotherapeutic treatment consisting of baking, massage, and active and passive motion was started and continued for 6 weeks. At the end of this time the patient was able to bear weight upon the hip without pain. Active motion was present to the extent of 80 degrees' flexion, 45 degrees' abduction, and 30 degrees' adduction. Six months later, the patient stated in a follow-up letter that motion and strength of the hip were improving very satisfactorily.

In the earlier cases of posterior dislocation in this series, preliminary skeletal traction was not employed and, as a result, many difficulties were encountered in effecting reduction even after the head and the acetabulum had been isolated. In most instances, efforts at manipulation and traction failed and the head was replaced only by the use of a steel lever. Crushing injuries of the head frequently followed the application of this instrument. In the hope of overcoming such difficulties, preliminary skeletal traction (technique of Van Gorder) was employed in the latter 5 cases, and, in each instance, it was possible to pull the head down to the level of the acetabulum before open arthrotomy. The traction was maintained for periods of time varying from 1 to 5 weeks. The weights were gradually increased from 5 pounds up to 20 or 25 pounds. Measurements of the extremity were made daily and when the length approached normal, roentgenograms were taken to determine accurately the position of the

Fig. 10B. The same hip shown in Figure 10A after 10 days of skeletal traction. This picture was taken before the open arthrotomy. It shows that the head has been pulled down to the level of the acetabulum. Stereoscopic views revealed that the head was still dislocated posteriorly.

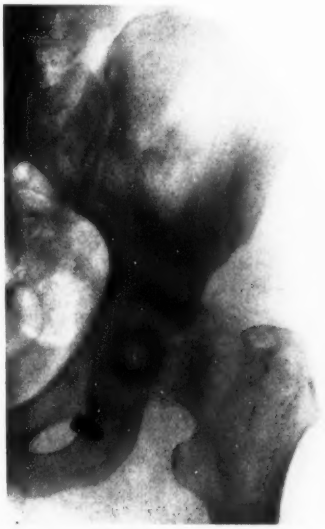

Fig. 10C. The same hip shown in Figures 10A and 10B, 5 weeks after open reduction. Aseptic absorption of part of the head may be seen.

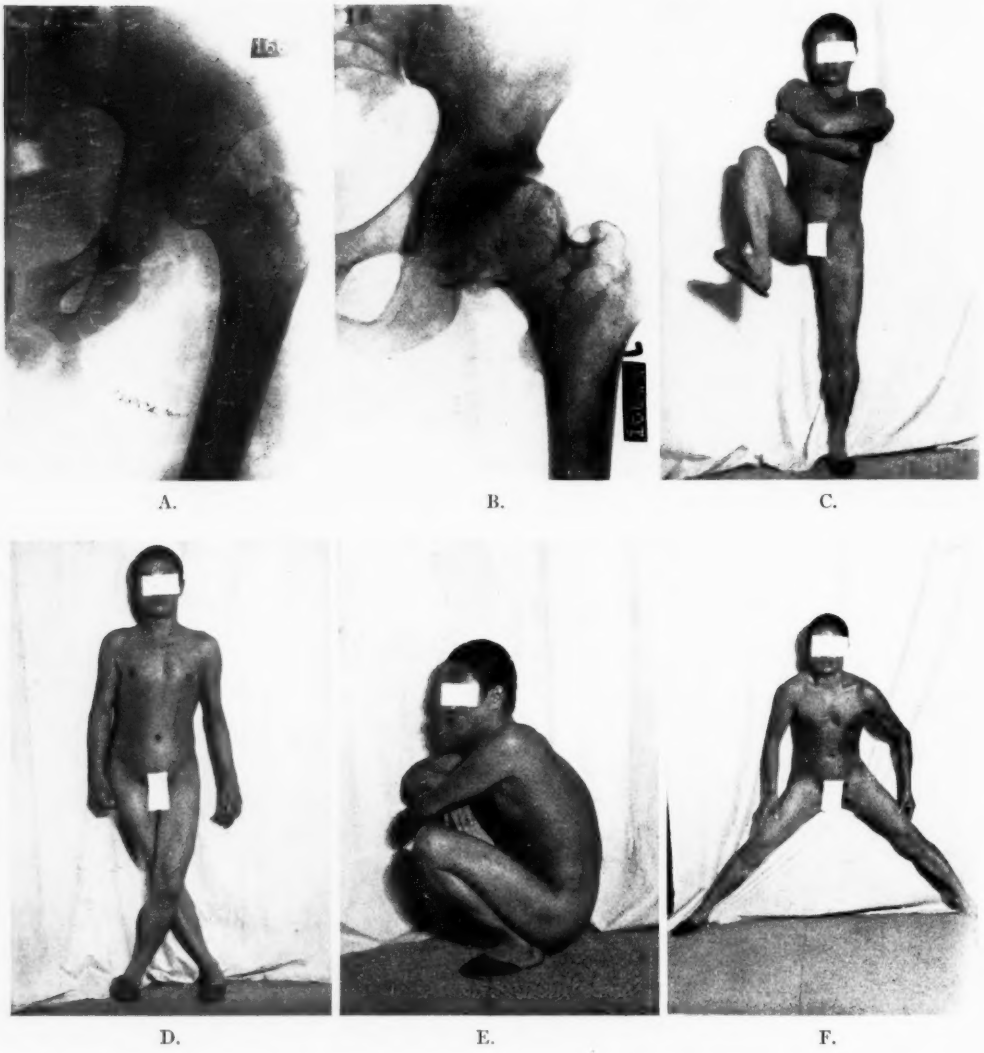

Fig. 11. Illustrations of a case of posterior dislocation of the hip with excellent result following open reduction. A, Pre-operative roentgenogram of left hip, illustrating a posterior dislocation of 18 weeks' duration. B, Post-operative roentgenogram of the same hip. Photograp C, D, E, and F show motion of the left hip 3.5 years af operation.

femoral head. If the X-ray films showed that the head had been pulled down to the level of the acetabulum, the hip was then considered ready for open reduction. By the use of this method, the trauma of open arthrotomy was decreased to a great extent and in each of the latter 5 cases complete replacement was accomplished by gen manipulation (Figs. 5A and B, and 10A and

THE DANGER OF SECONDARY INFECTION

CASE 2. A Chinese male, 41 years of age, was first s on March 23, 1925. The entrance examination was

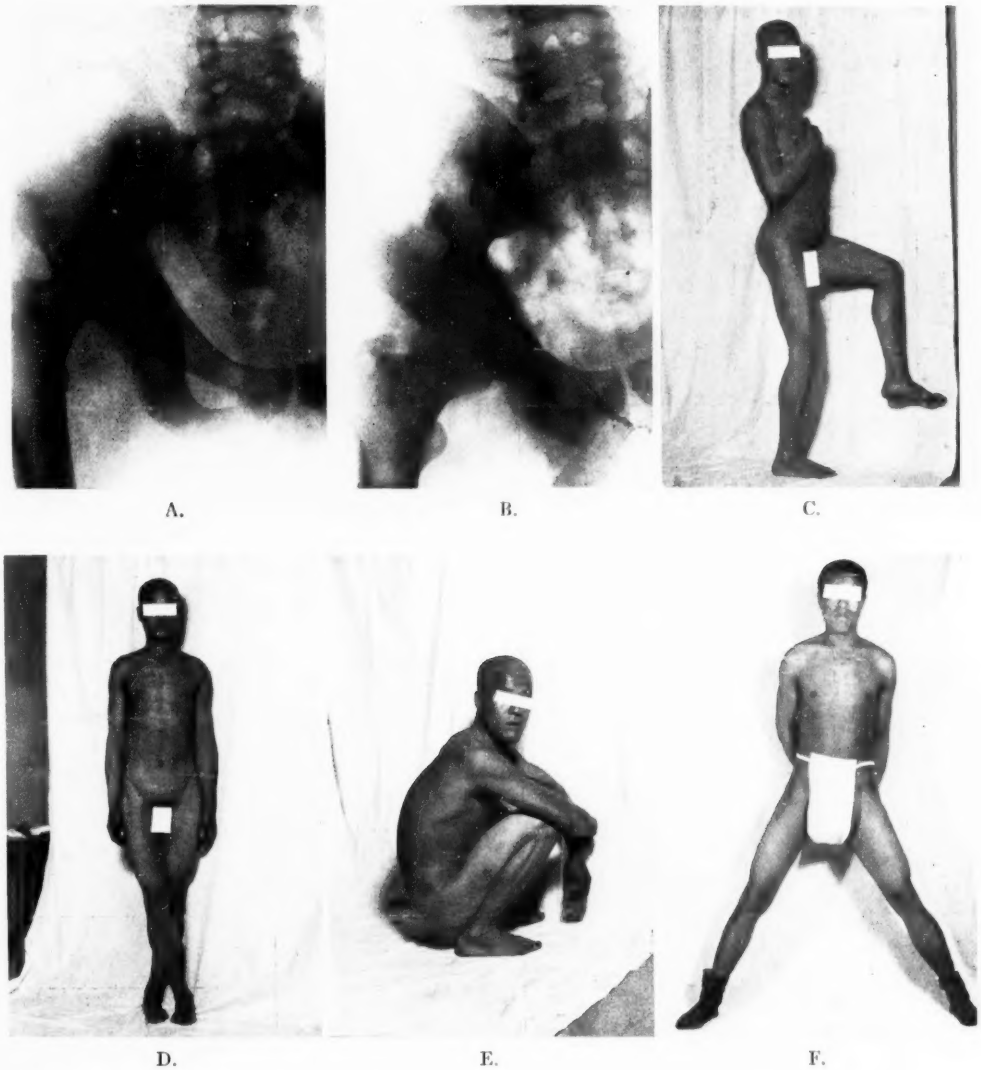

Fig. 12. Illustrations of a case of posterior dislocation of the hip with excellent result following open reduction. A, Pre-operative roentgenogram of the dislocated right hip (one year). B, Postoperative roentgenogram of the same hip. Photographs C, D, E, and F show motion of right hip 2 years after operation.

sentially negative except for a posterior dislocation of the left hip which was of 8 months' duration. The left lower extremity was in the characteristic position (flexion, adduction, and internal rotation), and weight bearing was moderately painful. Roentgenograms showed complete backward dislocation of left femur, head lying against ilium above acetabulum. A small amount of new bone was seen in secondary capsule surrounding the head of femur.

Open reduction without preliminary traction was performed with the patient under ether anæsthesia. A Smith-Petersen approach to the hip joint was made, the incision extending from the anterosuperior spine of the ilium downward along the lateral edge of the sartorius muscle and backward along the crest of the ilium. Dissection was continued between the sartorius and rectus femoris and between the ilium and the periosteal origins of the gluteus

TABULATION OF CASES

Average Duration of Postoperative Observation—2.2 Years

Age, sex	Duration of dislocation	Type	Complications of dislocation	Method of reduction	Result
28 M	1 mo.	Posterior (sciatic). Right side	Linear fracture of head of femur. Chip fracture of posterior rim of acetabulum. Supracondylar (T) fracture of right femur	Closed reduction (Bigelow). Supracondylar fracture treated by skeletal traction	Excellent. Complete reduction of hip. Six months later hip showed 75 per cent of normal motion; knee showed 70° flexion with arthritic pain on overuse
36 M	4½ mos.	Anterior (obturator). Right side	Intrapelvic dislocation of head with new bone formation	Closed reduction (reversed Bigelow). Manipulation prolonged and difficult, followed by large hæmatoma	Fair. Part of femoral head fractured and remaining portion of head placed in acetabulum. Fibrous ankylosis in good position. One year later considerable pain on overuse
23 M	3 wks.	Posterior (sciatic). Left side	None	Closed reduction (Bigelow)	Excellent. Motion almost complete and painless one month after reduction
23 M	3+ wks.	Posterior (sciatic). Right side	None	Closed reduction (Bigelow)	Excellent. Motion almost complete and painless 3 months after reduction
26 M	6 mos.	Posterior (high dorsal). Right side	None	Open reduction. Posterior approach; exposure of acetabulum very difficult. Manipulation during arthrotomy caused crushing injury to head	Fair. Reduction complete. Partial fibrous ankylosis present after 6 mos. Considerable pain on overuse. Followed for 6 years. Chronic traumatic arthritis of hip
41 M	8½ mos.	Posterior (high dorsal). Left side	Some new bone formation about dislocated head	Open reduction; anterior approach	Poor. Reduction complete but secondary infection (osteomyelitis) followed. Two years later hip ankylosed in good position. Chronic pain and disability. Observed 3½ years
27 M	3¼ mos.	Posterior (sciatic). Left side	Chip fracture of postero-inferior margin of acetabulum	Open reduction; anterior approach	Poor. Reduction complete but secondary infection (osteomyelitis) followed. After one year ankylosis in good position with painless weight bearing hip. Observed 4 years
40 M	5 mos.	Posterior (sciatic). Left side	Healed fracture of head. Marked osteoporosis	Open reduction; anterior approach. During arthrotomy head of femur bruised	Good. Reduction complete. Partial fibrous ankylosis. Function of hip good. Observed 10 months
50 F	3 mos.	Posterior (sciatic). Left side	Chip fracture of posterior superior acetabular rim	Open reduction; anterior approach	Excellent. Reduction complete. Motion and function 95 per cent after one year. Observed 7 years
60 F	3 mos.	Posterior (sciatic). Right side	None	Open reduction; anterior approach	Excellent. Reduction complete. Patient developed useful range of painless motion. Observed 2 months
34 M	3 mos.	Posterior (sciatic). Left side	Bullet struck head of femur causing a posterior dislocation of hip with fracture of head and superior rim of acetabulum. No infection	Pre-operative skeletal traction very effective. Open reduction; anterior approach	Excellent. Reduction complete. Fibrous ankylosis of hip in good position. No infection. Observed 14 months
28 M	12 mos.	Posterior (high dorsal). Right side	Chip fracture, posterior rim of acetabulum	Pre-operative extension (Buck's) ineffective. Open reduction; anterior approach	Excellent. Reduction complete. Almost normal range of motion. Slight traumatic arthritis present after 2 years
26 M	12 mos.	Posterior (sciatic). Right side	Marked osteoporosis of head and neck. Some flattening of the head probably due to old crushing injury	Pre-operative skeletal traction very effective. Mild osteomyelitis in lower end of femur. (Steinmann pin.) Healed after several months. Open reduction; anterior approach	Fair. Reduction complete. Marked osteo-arthritic changes developed hip with limited motion and pain overuse. Observed 1 year
18 M	4 yrs.	Posterior (sciatic). Left side	None	Pre-operative skeletal traction very effective. Open reduction; anterior approach	Fair. Reduction complete. Sciatic nerve injured during arthrotomy. Repair tempted. Hip ankylosed in good sition with satisfactory weight bear Observed 2½ years
25 M	5 mos.	Posterior (sciatic). Left side	Healed chip fracture of posterior acetabulum and top of great trochanter	Pre-operative skeletal traction very effective. Open reduction; anterior approach	Excellent. Reduction complete. M was 90 per cent normal after one Function very good. No pain. served 3½ years
35 M	3 mos.	Posterior (high dorsal). Right side	Healed chip fracture of posterior acetabulum	Pre-operative skeletal traction very effective. Open reduction; anterior approach	Excellent. Reduction complete. M was 85 per cent normal after 7 mo Function very good. No pain

minimus and medius muscles. This exposed the entire region of the acetabulum and showed it to be filled with dense tissue across which stretched the scarred tendinous mass of the iliopsoas muscle. The mass of scar tissue was dissected out piece by piece, revealing intact cartilage within the acetabulum. After the head and neck of the femur were freed from the adjacent scar tissue, an attempt was made to reduce the dislocation. This failed despite the fact that great force was used in pulling down the leg and manipulating it. Further attempts also failed until finally, with the help of a large steel skid, reduction was completed. During the latter procedure a portion of the head of the femur was bruised and the cartilage torn off despite all efforts to prevent injury. The wound was closed in the usual manner and the leg was placed in a splint in a position of 30 degrees' abduction.

Following this operation the patient's temperature varied from 38 to 40 degrees centigrade. Five days later the wound was reopened because of obvious secondary infection. A staphylococcus osteomyelitis of the hip followed and two incisions were necessary for drainage. The infection was rather severe and was followed by extensive destruction of the acetabulum and of the head of the femur. Roentgenograms taken 6 months later showed definite bony ankylosis of the hip (Fig. 7). The patient was able to walk satisfactorily. The patient was under observation for 3 years, during which time he suffered from several attacks of pain associated with renewed drainage from the hip.

OPERATIVE INJURY TO THE SCIATIC NERVE

Case 3. A Chinese male, aged 18 years, was first seen on April 5, 1929. The entrance examination revealed a posterior dislocation of the left hip which was the result of a fall 4 years previously. Roentgenograms showed that the head of the femur was lying on the ilium in the region of the greater sacrosciatic notch. The upper portion of the head appeared somewhat flattened and osteoporotic as a result of the old injury. The general physical examination was essentially negative except for the condition of the hip.

On April 9, 1929, traction was started by means of a Steinmann pin inserted through the lower end of the femur. The weights were gradually increased up to 15 pounds and traction was continued for 5 weeks. At the end of this time roentgenograms showed that the head of the femur had been pulled down to the level of the acetabulum; its anterior surface resting against the posterior margin of the socket. On May 17, 1929, open arthrotomy was performed. Ether anæsthesia was used and a Smith-Petersen incision was made. Exploration showed that the acetabulum was filled with dense fibrous tissue. This mass of tissue was removed, exposing the intact cartilage. The secondary capsule was opened anteriorly and upon external rotation a portion of the head could be seen. The upper end of the shaft and the neck were held securely to the pelvis posterior to the acetabulum. When the fibrous bands were cut through, a branch of the superior gluteal artery was severed. Considerable hæmorrhage followed and while we were working in a rather bloody field the sciatic nerve was divided. Apparently the nerve had been fastened to the posterior surface of the secondary capsule. Following the hæmorrhage the patient showed a weak pulse and in the hurried dissection which followed, repair of the sciatic nerve was not performed. The head of the femur was completely reduced. A transfusion of blood was given immediately after the operation and the patient returned to the ward in satisfactory condition.

Two weeks later repair of the sciatic nerve was attempted but the proximal portion had retracted into the pelvis so that end-to-end anastomosis was impossible. The hip was immobilized and 4 months later fibrous ankylosis was almost complete. Observations 1 and 2 years later showed that the hip was ankylosed in good position. The patient walked satisfactorily with the aid of a footdrop brace.

A FRACTURE CAUSED BY LATE MANIPULATION

Case 4. A Chinese male, aged 36 years, was first seen on July 1, 1925. Four and one half months previously he had been thrown from a wagon in such a manner as to dislocate his right hip. The general history and physical examination revealed nothing of importance. The results of routine laboratory tests of the blood and urine were normal. Local examination showed the right lower extremity to be in a position of 40 degrees' abduction, 45 degrees' external rotation, and 45 degrees' flexion with actual lengthening to the extent of 3 centimeters. Roentgenographic examination revealed that the head of the femur was totally displaced through the posterior part of the obturator foramen (Fig. 8A). A layer of dense bony material covered most of the surface of the dislocated head. This appeared to be calcified, ligamentous, and periosteal tissue. The inferior rim of the acetabulum was fractured but the femoral head seemed intact except for a moderate amount of osteoporosis.

On July 10, closed reduction was performed with the patient under ether anæsthesia. During the manipulations which were necessarily very severe and prolonged (1 hour) a cracking sound was heard. Following this the head of the femur slipped into the region of the acetabulum. A splint was applied and the patient returned to the ward in good condition. Roentgenograms taken immediately after the manipulation showed that reduction was quite satisfactory but at the expense of a fracture through the head. Several broken fragments of the femoral head remained in the obturator foramen (Fig. 8B).

Following the trauma of reduction a large hæmatoma developed in the right groin and for 8 days the patient ran a fever varying from 38 to 39 degrees centigrade. Two weeks after reduction a course in baking, massage, and active and passive motion was instituted. Two months later the patient walked upon the right leg but still complained of pain. He then had about 60 degrees of flexion but motion in other directions was greatly limited. In a follow-up letter one year later the patient stated that the hip was painful upon bearing weight but nevertheless was greatly improved when compared to the previous condition.

LATE ARTHRITIS FOLLOWING OPEN REDUCTION

Case 5. A Chinese male, aged 28 years, was admitted to the hospital on August 23, 1926. The patient stated that 12 months previously he had fallen from a tree injuring severely the right hip. The entrance examination was essentially normal except for the right hip which was carried in the usual position of posterior dislocation. Roentgenograms showed the head of the femur lying on the posterior surface of the ilium in the region of the great sacrosciatic notch (Fig. 9A).

Traction by means of adhesive tape was maintained for 11 days, but had little effect on the measurement of the distance between the anterosuperior spine and the internal malleolus. On September 3, 1926, open reduction was performed. Ether anæsthesia was used and a Smith-Petersen incision made. Following deep dissection, a triangular flap of skin, fascia, muscle, and periosteum was retracted from the blade of the ilium. Subperiosteal dissection gave very satisfactory exposure of the acetabulum and the dislocated head of the femur. The acetabulum was filled entirely with fibrous tissue, the removal of which required force and sharp dissection. Intact surfaces of cartilage were found.

When the secondary capsule was opened the head of the femur was found in the region of the greater sacrosciatic notch. The cartilaginous surface of the head was intact except in one small area where it appeared thinned and flattened as though the underlying bone had been crushed. The tendinous fibers of the obturator internus and pyriformis muscles lay in a mass of scar tissue which firmly held the base of the neck of the femur to the posterior margin of the acetabulum. These two tendons had been wound around the neck as they passed on to their insertions into the region of the great trochanter. After the upper end of the femur was released by sharp dissection, reduction was obtained by manipulation and traction. A long leg hip spica cast was applied and the patient had an uneventful convalescence.

Following 3 months of physiotherapeutic treatments, the functional result was excellent, with almost 75 per cent of the normal range of motion. On November 13, 1929 (3 years after operation), the patient returned for follow-up examination. The only complaint was slight pain after long periods of walking. Roentgenograms taken at that time showed that a large amount of new bone had developed around the head and neck of the femur (Fig 9B). It was very surprising to find excellent function existing in the presence of such marked osteo-arthritic changes.

POSTERIOR DISLOCATION OF THE HIP CAUSED BY THE TRAUMA OF A RIFLE BULLET

CASE 6. A Chinese male, aged 34 years, was first seen on June 30, 1930, for an old gunshot injury (80 days) in the region of the left hip with retained foreign body. The wound had healed spontaneously 1 week after injury. The general physical examination was normal except for the condition of the hip. The laboratory examinations revealed no abnormal findings. The left thigh was held in a position of flexion (35 degrees), adduction (30 degrees) and internal rotation, and the greater trochanter was 4 centimeters above Nélaton's line. Roentgenographic examination of the hip confirmed the impression of posterior dislocation. It also showed a fracture of the head of the femur along with a fracture of the superior rim of the acetabulum (Fig. 10A). The foreign body was seen in the region of the left obturator foramen. There was no evidence of any infectious process in the hip.

On June 23, 1930, a Steinmann pin was inserted through the lower end of the femur and preliminary traction was started. Seven days later, on July 1, 1930, the leg had been pulled down to its normal level (Fig. 10B). Three days later an open arthrotomy was performed through a Smith-Petersen incision. All the scar tissue was cleaned out of the acetabulum. Upon opening the capsule, the head of the femur was seen to be fragmented in the inferior portion—changes suggesting the gradual absorption seen in aseptic necrosis (Axhausen, Phemister). Cultures taken from the head showed no growth. The dislocation was easily reduced by manipulation. The wound was closed in the usual manner and a plaster hip spica was applied with the thigh in a position of 20 degrees' abduction. The patient had an uneventful convalescence and was discharged in a cast 13 days after operation. One month later the cast was removed and physiotherapy was started. Roentgenographic examination at that time showed an increased amount of absorption of the injured area of the head and acetabulum (Fig. 10C). Three months later the patient walked satisfactorily. The hip had undergone almost complete fibrous ankylosis. One year and 2 months following the operation the patient reported that he was able to work 7 hours daily. His only complaint was slight pain in the hip upon overuse.

SUMMARY

1. A review and discussion of the reconstructive surgery of old traumatic dislocations of the hip is presented.

2. Sixteen cases of old traumatic dislocation of the hip (15 posterior, 1 anterior) are reported. Three cases of 21 to 31 days' duration were reduced by closed manipulation after the method of Bigelow. One case of obturator dislocation of 4½ months' duration was reduced by the closed method at the expense of fracture of the head of the femur. By open arthrotomy complete reduction was accomplished in the 12 remaining cases.

3. The use of skeletal traction preliminary to open arthrotomy is emphasized.

Acknowledgment is due to Drs. G. W. Van Gorder, A. S. Taylor, J. P. Webster, and L. C. Chu, whose cases are included in this study.

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A TYPE OF PELVIS INTIMATELY ASSOCIATED WITH OCCIPITO-POSTERIOR POSITION

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IN speaking of the differences in the configuration of the human pelvis, William Turner in 1886 wrote, "with the exception of the skull no portion of the skeleton presents greater individual variations than the pelvis." These variations may have a profound effect upon the course and character of labor as is well known to obstetricians, and the pronounced types of contracted pelvis are well known and readily recognized. On the other hand, there are many slight or moderate variations from the normal which remain unrecognized.

In the present paper I wish to speak of pelves in this latter group, especially those characterized by a moderate or pronounced shortening of the transverse diameter of the superior strait often in association with abnormal lengthening of the anteroposterior diameter. I am convinced that this type of pelvis occurs with relative frequency, and that it has a distinct influence upon the course of labor, two facts that have not been sufficiently emphasized. My conclusions are drawn from a radiological study of pelves now extending over twelve years. This experience has proved to me what I have on numerous occasions emphasized, namely, that the usual methods of external pelvimetry do not offer an accurate picture of the superior strait and at best can be considered only as guideposts to the true dimensions of this plane of the pelvis. It is, therefore, not surprising that moderate or even pronounced shortening of the transverse diameter of the superior strait should escape recognition, for until the advent of roentgen methods there was no accurate diagnostic procedure available for pelvic mensuration of the superior strait.

It is an interesting historical fact that the plate depicting the pelvis in the great work of Vesalius shows the sacrum with six instead of five segments; so also does Deventer's, *New Light for Midwives*, 1725. Sacral bones containing six segments are definitely associated with transverse shortening of the superior strait so that these plates do not depict what the authors undoubtedly intended, namely, the normal pelvis.

In all mammals except man the transverse diameter of the superior strait is shorter than the anteroposterior. This relationship is known as the dolichopellic pelvis in contrast to the platypellic pelvis in which the obverse obtains, namely, the transverse is longer than the anteroposterior diameter. The platypellic pelvis is characteristic of the human species. The dolichopellic pelvis obtains throughout in the anthropoid apes, and Turner states that when it occurs in humans there exists an "animalized" arrangement.

In the pelvis of the newborn child the superior strait is narrower than in the adult, the ratio of the anteroposterior to the transverse diameter being 100:105 instead of 100:122.5 as in the latter. Fehling first pointed out that differences in form and appearance of the male and female pelvis are noted as early as the third month of fetal life and Thompson noted at this period differences similar to those of the adult. In his series the male index was 86 as against the female index of 83.

$$\text{Pelvic Index} \left\{ \frac{\text{Conjugate diameter} \times 100}{\text{Transverse diameter}} \right.$$

When we study the essential differences of the adult male and female pelvis, we find among other characteristics that the transverse diameter of the superior strait in the male is shorter than that of the female, thus giving this plane in the former a more rounded appearance.

Berry Hart states that the ultimate shape of the pelvis is due mainly to a type growth before birth and not wholly to postnatal mechanical influences. He concludes nevertheless that the lumbar curve, the greater curve of the sacrum, and the inclination of the pelvic brim to the horizon are all due to postnatal influences. He has thus classified the more common pelvic variations in this interesting manner.

Congenital which include,

1. Normal female
2. Inverted pelves (i.e., male type)
3. Justominor
4. Naegele
5. Robert
6. Achondroplastic
7. Infantile
8. Funnel
9. Assimilation

Postnatal which include,

1. Flat
2. Flat rachitic
3. Scoliorachitic

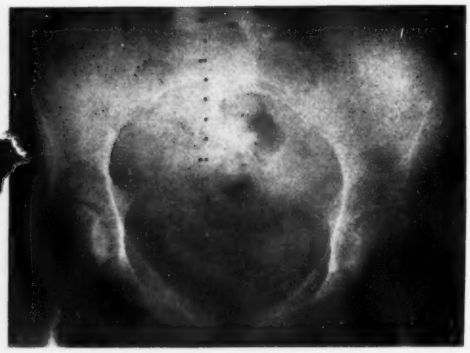

Fig. 1. Roentgenogram of pelvis showing unilateral high assimilation. Anteroposterior diameter, 12.0 centimeters; transverse diameter, 12.0 centimeters.

In the above classification the inverted or male type pelvis is of unusual interest to us because its characteristics are,

1. Smaller ilium
2. Smaller sacrum
3. Male type sacrosciatic nitch
4. Symmetry of pelvis
5. Narrowing of transverse of brim

Nearly every textbook of obstetrics mentions the occurrence of the male type of pelvis in the female. When we consider that the essential difference from an obstetrical viewpoint is a decrease in the transverse diameter of the superior strait and of the outlet, it is reasonable to suspect that these changes may exert a definite influence on labor. In a recent paper by Cornell on "The Conduct of Labor in the Dystocia Dystrophia Syndrome Patient" although no specific attention was given to the exact type of pelvis present in the series (that is, no outlet or X-ray measurements are mentioned), the description of the heaviness of the pelvic bones, the *relative increase in the external conjugate diameter*, and the frequent occurrence of occipitoposterior position leads me to the conclusion that shortening of the transverse diameter of the superior strait is probably also present in this type of patient.

Shortening of the transverse diameter of the superior strait is also characteristic of the high assimilation pelvis. It will be recalled that in this variation the transverse processes of the last lumbar vertebra fuse with those of the first sacral. By this process the last lumbar becomes the first sacral vertebra, the sacrum then being composed of six instead of five segments.

Occasionally in high assimilation one side of the last lumbar vertebra undergoes this fusing process while the other side does not, as is shown in the accompanying roentgenogram (Fig. 1). In Paterson's study of 265 dried pelves this unilateral assimilation occurred in 18, or 6.79 per cent, while 61, or 23 per cent, showed the presence of more than five sacral vertebræ. Emmons, in an analysis of 217 Indian squaw pelves, found the incidence of assimilation to be 21.7 per cent.

From these studies we conclude that high assimilation is of relative frequency and is definitely associated with shortening of the transverse diameter of the superior strait. Indeed, occasionally this variation of the pelvis gives rise to a dolichopellic pelvis.

One of the most interesting clinical reports on this subject is that of Fabre and Trillat in 1920. They record the results of a radiographic study of 12 pelves which they designate as "Pelvis with anteroposterior diameter predominating." In all of their series the fifth lumbar vertebra was sacralized, i.e., high assimilation was present. In seven of these, delivery occurred with the occiput posterior. Fabre and Trillat conclude, "for us this has the relation of cause and effect, a

TABLE I.—SUMMARY OF FIGURES

Case	Antero-posterior diameter cm.	Differences	Transverse diameter cm.	Course of labor
1	11.0	+ .75=	11.75	L.O.P. forceps
2	10.75	+ .25=	11.0	R.O.P primary
3	13.5	− .25=	13.25	R.O.P. persistent
4	10.5	+ .5 =	11.0	R.O.P. primary
5	14.0	−1.0 =	13.0	R.O.P. persistent, forceps
6	12.0	+ .75=	12.75	R.O.P. persistent, forceps
7	12.0	+ .75=	12.75	L.O.P. primary
8	12.0	−1.0 =	11.0	R.O.P. persistent, forceps
9	10.75	+1.0 =	11.75	R.O.T. low transverse arrest, forceps
10	13.75	−2.5 =	11.25	R.O.P. persistent, forceps
11	12.0	=	12.0	R.O.P. primary
12	12.5	− .5 =	12.0	R.O.P. primary
13	13.0	− .75=	12.25	R.O.P. primary
14	12.25	− .25=	12.0	R.O.T. small baby (2360 grams.)
15	11.0	+1.0 =	12.0	L.O.T. low transverse arrest, forceps
16	11.75	=	11.75	R.O.P. primary
17	12.75	+ .25=	13.0	R.O.P. primary, forceps from R.O.T.
18	10.75	+ .25=	11.0	L.O.P. persistent, forceps
19	12.0	+ .50=	12.5	R.O.P. persistent, forceps
20	13.25	− .50=	12.75	R.O.P. primary

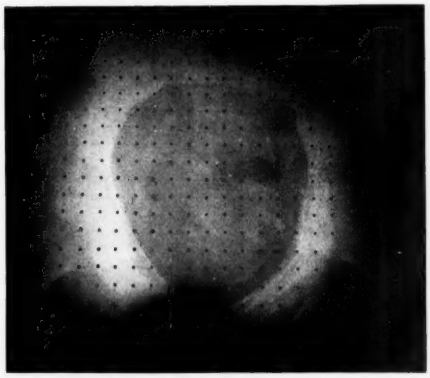

Fig. 2. Roentgenogram of pelvis (dolichopellic type). Anteroposterior diameter, 13.0 centimeters; transverse diameter, 11.0 centimeters.

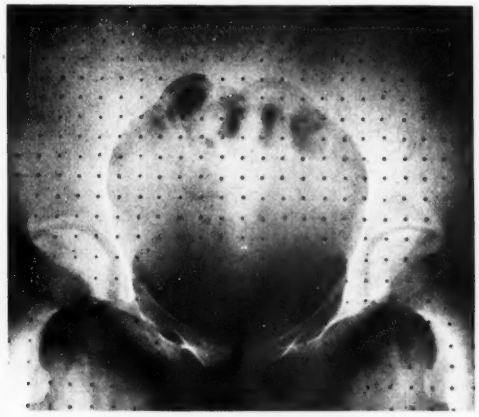

Fig. 3. Roentgenogram of pelvis (dolichopellic type). Justomajor external measurements: anteroposterior diameter, 13.0 centimeters; transverse diameter, 12.75 centimeters.

we believe that this special form of the superior strait, which we have shown in radiographic measurements, and to which we have applied the name pelvis with anteroposterior diameter predominating is the principal cause of births in the occipitoposterior position."

I am convinced that not only are such pelves as these authors describe associated with occipitoposterior position, but that lesser degrees of transverse contraction, whether due to assimilation, male type of pelvis, or to unnamed causes are definitely associated with both primary and persistent occipitoposterior position. I am also of the opinion that many pelves which from their external measurements are classified as generally contracted are contracted only or chiefly in the transverse diameter of the superior strait. These are the so called small round pelves. In many of these the diagonal conjugate diameter is within the limits of normal.

During the past year in connection with our roentgen pelvimetry and cephalometry studies, I have been impressed with the frequency of the occurrence of pelves in which the chief deviation from normal is a relative or real decrease in the transverse diameter of the superior strait. Twenty such pelves have been studied, particularly in reference to the course of labor.

The first 16 of this series have been reported in detail in another publication. An important point in this study is the fact that the series represents 20 consecutive cases of this type and that every one was associated with primary or with persistent occipitoposterior position.

A summary of the figures obtained from our study is shown in Table I.

The diagnosis of position in all instances was made by vaginal examination during labor. Those cases which are designated as primary posterior position subsequently delivered with the occiput anterior, while in 2 cases which were delivered by forceps from low transverse arrest I assume the occiput entered the pelvis in the posterior position. In only 2 instances did the transverse diameter of the superior strait exceed the anteroposterior diameter by as much as 1.0 centimeter (normal 2.5), while in one instance, in a patient with justomajor external measurement, the transverse diameter was actually less by 2.5 centimeters than the anteroposterior diameter, a true dolichopellic pelvis.

I regret that in this group I cannot report upon the incidence of high assimilation. In order to determine accurately the presence of this entity either lateral or direct anteroposterior pelvigrams should be taken. In the system of roentgen pelvimetry which we employ it is not possible in the developed film to count the sacral segments. Nevertheless, in one case of outspoken transverse diameter shortening, a lateral pelvigram showed only the usual number of sacral vertebræ. My belief is that shortening of the transverse diameter of the superior strait does occur frequently in the absence of high assimilation or other outspoken pelvic anomaly.

In reviewing our findings, I am mindful of a sentence from the writings of Sir Oliver Lodge which reads: "always we must be guided by experience and be loyal to facts whether we understand them or not." The facts stated are cer-

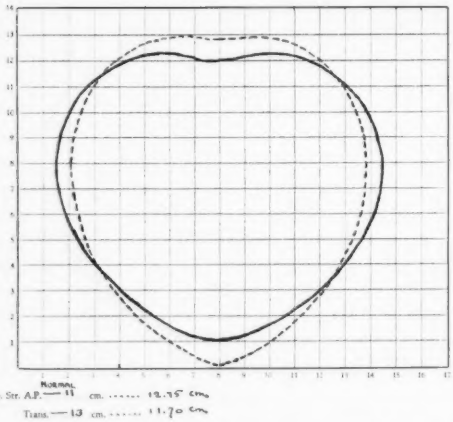

Fig. 4. Normal pelvis, solid line; composite pelvis, dotted line.

tainly interesting and certainly not easy of complete understanding. When one surveys statistics dealing with the incidence of posterior presentations, he becomes involved in a maelstrom of figures which are largely meaningless. Thus Pinard gives an incidence of 38.8 per cent while Williams, in a large series, reports 11.68 per cent. The latter writer, however, states that the incidence is probably twice this figure. I think that 20 per cent for primary occipitoposterior positions probably represents a figure somewhere near the truth. It is, of course, an interesting speculation as to the real cause of the high incidence of occipitoposterior position in the series here presented. My own interpretation of the facts may be stated briefly. If we consider 11 centimeters for the normal conjugata vera and 13 centimeters for the normal transverse of the inlet, and apply them to the figures for these diameters in the above series we see two interesting facts. First, in 17 of the 20 cases the transverse diameter is less than the normal figure, and in 14 of the series the anteroposterior diameter actually exceeds the normal figure. The average figures are: transverse diameter 1.31 centimeters less than the normal, conjugata vera 1.75 centimeters more than normal. If we visualize these figures in the accompanying diagram (Fig. 4), the solid line representing the normal pelvis and the dotted line representing a composite pelvis based on the figures mentioned, I think we can agree that the occiput would assume a primary posterior position much more readily in the latter than in the former. I am well aware that other factors may enter into the cause of occipitoposterior position. When one reads the amazing list of suggested causes in modern textbooks the aggregate is most bewildering. However, I am convinced that the shape of the pelvis and particularly the type of pelvis present in this series, is a most potent factor in the production of primary occipitoposterior position. In reducing this type of pelvis to an entity, in which the chief variations seem to be a prolongation of the anteroposterior diameter in combination with a moderate shortening of the transverse diameter it may appear like putting the cart before the horse to call it a transversely contracted pelvis; perhaps the elongated anteroposterior pelvis is more descriptive.

I summarize my impressions as follows:

1. The type of pelvis described here is far more common than heretofore appreciated.

2. The extraordinary incidence of primary and secondary occipitoposterior positions noted indicate that this type of pelvis is a most potent factor in the production of this position.

3. Unless we make an *accurate* survey of the pelvis of every primiparous patient we are not doing our whole duty to the patient or practicing modern scientific obstetrics.

4. At the present time an accurate survey of the superior strait in the living subject can only be secured by roentgen pelvimetry.

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ROENTGEN MEASUREMENTS IN PREGNANCY

A Few Practical Methods and a Simplified Procedure Used by the Author

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THE taking of pelvic measurements in obstetrics in some manner or another is nearly as old as the subject of obstetrics itself. As the study of pelvimetry as a diagnostic procedure advanced, it was found and generally conceded that external pelvic measurements were not indicative of the size of the inner pelvis as they were formerly thought to be and it was therefore concluded that the only pelvic measurements of any value were those obtained by taking internal measurements. For this latter type of procedure many methods and many instruments were devised. In some hands this procedure seemed to have considerable value in obtaining the desired information regarding the size and shape of the inner pelvis. The chief objections, however, have been mainly the distress it causes most patients and the lack of ability in the hands of many to obtain what could be called accurate results.

To know the exact size and shape of the true pelvic inlet is admitted by all to be of extreme diagnostic value in any obstetrical procedure. It is also true that the size and shape of the superior pelvic strait is more important than is that of any other pelvic region, due chiefly to the fact that this location is most subject to variation in any disease of the bones of the pelvis.

The false pelvis which is formed by the flaring of the iliac bones above the opening of the true pelvis is of very little importance in the conduct of labor. During pregnancy it gives some support to the fetus and is instrumental in directing the head of the child into the true pelvis just prior to or at the time of labor.

The true pelvis itself is an elongated, curved canal composed of bony, fibrous, and muscular tissue. This canal is also made up of three anatomical regions, the entrance or inlet, the canal proper, and the outlet. It is the entrance of this true pelvis that we are particularly interested in for the reason stated.

While it must be admitted that many other things enter into the successful conduct of labor, such as the strength of the uterine muscle, the relaxation of the iliopsoas muscles and the other soft tissues, the condition of the patient's kidneys, her heart and her general mental and physical makeup; nevertheless, the size and shape of the pelvic inlet remain as a diagnostic element of extreme importance. As the size of the child's head is fairly constant and not subject to much variation, the size and shape of the inlet is considered the most important.

In contrast to the waning methods of internal pelvimetry by manual and instrumental means, we now have the gradual advancement of the more popular procedure of roentgen pelvimetry and its associated method cephalometry. The major part of this work, however, at the present time is still confined to the larger medical centers, their teaching hospitals and radiological laboratories, and it is no fault of the procedure that at the present time it is not more universally used. There are, however, two conditions preventing this method from being more generally in vogue. One is a lack of knowledge of the procedure among many practitioners interested in obstetrics. The other is an opinion among many that the method involves extreme technicalities and can only be performed in highly specialized X-ray laboratories. This latter statement is not true and there are many physicians today, both in large and small communities, doing obstetrics who have their own X-ray laboratory or who have access to X-ray laboratories in the hospitals in which they work, who could with very little effort make use of this valuable diagnostic procedure.

When we stop to consider that in this country alone upwards of twenty thousand women annually lose their lives from some complication of childbirth and that more than three times as many infants die at the time of birth, we will have to admit that the medical profession in this respect have a very fertile field of endeavor. And not only have we that to consider, but it is also true that upward of one-half of the gynecological operations performed are with the idea of correcting some condition that had its inception at the time of childbirth. Good obstetrics like every other field of medicine and surgery is dependent upon good diagnosis.

The subject of roentgen pelvimetry as a diagnostic procedure in obstetrics is older than one would ordinarily imagine. The roentgen rays or X-rays, as they were called at the time, were discovered by Roentgen in the fall of 1895. Scarcely 2 years had elapsed when Budin published an article in which he brought out the fact that it was

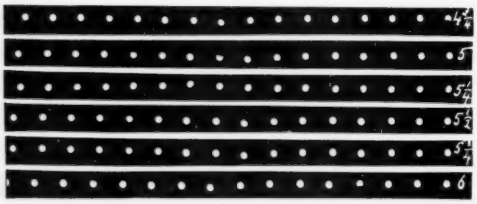

Fig. 1. Pubic scales used by Rowden.

more important to know the shape and circumference of the superior pelvic strait than that of the anteroposterior diameter. This article was based on the findings of a roentgenogram of a deformed pelvis.

This same year, 1897, Varnier wrote his first article entitled "Pelvigraphie et pelvimetrie par les rayons x" (Pelvic photographs and pelvic measurements by the use of X-rays). In this article he states that in the year 1896, in conjunction with other collaborators, work was begun on roentgen pelvimetry. The first roentgenograms were taken on the body of a woman who had died of intestinal obstruction 9 days following confinement. He also found that, due to the limited capacity of their X-ray equipment, it was very difficult to get roentgenograms that were very distinct, especially in large women or women in the latter half of pregnancy. In conclusion he remarks that it is possible by the use of X-rays to diagnose pelvic conditions that could not be diagnosed by any other means.

Albert, in 1899, published a very classical article entitled "Ueber die Verwertung der Roentgenstrahlen in der Geburtshilfe" (The use of X-ray in gynecology). The author advocated the use of the semi-recumbent position in order to get the superior strait in a parallel position with the film. He also used the upper margin of the fifth lumbar vertebra and the superior part of the symphysis as his locations for placing the superior strait in this parallel position. His calculations were made by a mathematical procedure in which known quantities, distance of superior strait from film, and focal distance of the tube were used.

Fabre and Fouchert in this same year wrote of their first work and described what is now commonly known as the Fabre method. The work of Budin, Varnier, Albert, and Fabre and Fouchert at this early stage seemed to establish roentgen pelvimetry as a definite procedure, and was the foundation from which the later work received its incentive.

From then on until the present time the British, French, German, and American workers have presented a succession of articles pertaining to this subject. These articles describe a variety of procedures and at the present time we have a great many valuable methods from which to choose.

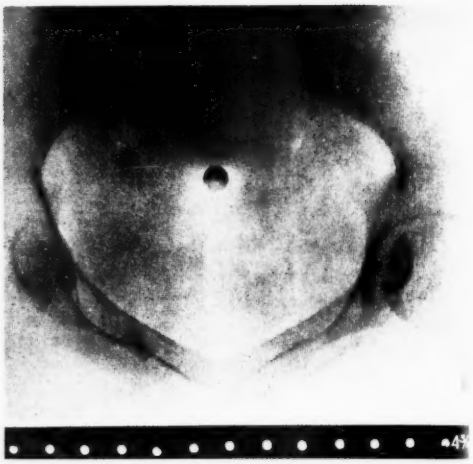

Fig. 2. Roentgenogram of pelvis with scale attached a used by Rowden.

Hirsch in the discussion of a paper by Thoms (28) in 1922 divided the various methods of roentgen pelvimetry into 5 types, comparative, teleoroentgenographic, frame, triangulation, and stereoroentgenographic methods. The classification is very complete and covers the entire field of roentgen pelvimetry from its inception.

1. *Comparative.* Radiograms taken of dried pelves. These are compared with radiograms of pelves of living individuals. A matching of radiograms, so to speak, and the referring back to the original dried pelvis for measurements.

2. *Teleoroentgenographic.* By establishing a long focal film distance with the superior strait of the pelvis parallel to the film, distortion is reduced to a minimum.

3. *Frame.* By this method a scale is superimposed at the same level at which the measurements are to be taken and when an exposure is made, the scale superimposed on the film, is distorted in the same proportion as the region to be measured. Measurements are then read directly on the film from the distorted scale.

4. *Triangulation.* A study of triangles with known quantities, the procedure involving the same principles of mathematics and radiology as used for the localization of foreign bodies.

5. *Stereoroentgenographic.* Patient is placed in such a position that the obstetrical la

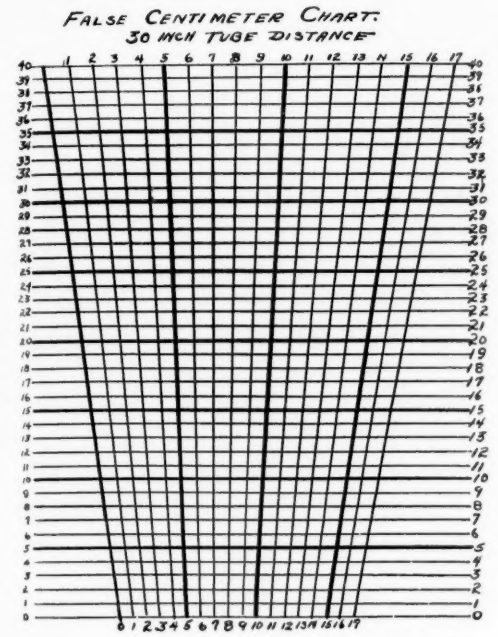

Fig. 3. Distorted centimeter graph as used by Walton.

marks to be used will best be seen on the film. Stereoscopic roentgenograms are taken with a known tube shift and a known focal distance. The film center must be known in relation to the focal point and the shift of the tube must be parallel to the film. Computations must be made by the use of precalculated tables and formulas or by means of mechanical devices used to reconstruct the problem involved.

I have classified the procedures according to the recognized methods in vogue today. They are as follows: (1) methods based on mathematical calculations alone; (2) methods based on mathematical calculations associated with triangulation and stereoroentgenographic procedures; (3) scale methods.

The two latter types are the ones most commonly used today.

The past 2 or 3 years seem to have divided the workers in roentgen pelvimetry into two schools. The one class striving for extreme accuracy but involving technical methods beyond the scope of the average physician, but methods well adapted to technical laboratories or in teaching hospitals; on the other hand a group of workers striving for practical methods easily performed and entailing the least amount of technical procedure but still

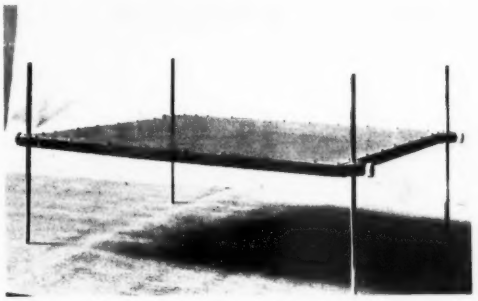

Fig. 4. Type of pelvimeter used by author. Somewhat similar in appearance to that of Thoms.

maintaining enough accuracy for all practical purposes.

There is no doubt but that each group has excellent reasons for the methods advanced, but it is also true that if roentgen pelvimetry is to be a thing of real worth, it will have to be of such a nature that it can be used and understood by the great majority of physicians doing obstetrics throughout this land. It will have to be practiced in the regions where twenty thousand women are annually losing their lives from complications of childbirth.

From a roentgenological standpoint every primipara and every woman who gives a history of difficult labor, when reporting to her physician and the diagnosis of pregnancy has been made, should have a roentgenogram taken to determine the dimensions and shape of the pelvic inlet. If it is found at this time that the patient has a small or distorted pelvic inlet the regular routines of diet and general care that are usually used can be followed out. Just prior to labor a roentgenogram can be taken to determine any evidence of distortion and if such is manifest the physician can resort to cephalometry.

Every case, whether primipara or multipara, should have a roentgenogram taken at approximate term to determine and diagnose the position of the child, the probability of multiple pregnancy, the possibility of malformed fetus, and the possibility of disproportion between the pelvic inlet and the head of the child. If there is any evidence of disproportion cephalometry can be resorted to. If any other abnormal condition is found, the physician can then plot his course as regards each individual case.

If that type of procedure along with the better present day methods of prenatal care is adopted and adhered to, a few years should show some results. The more prenatal care, the less natal and postnatal trouble.

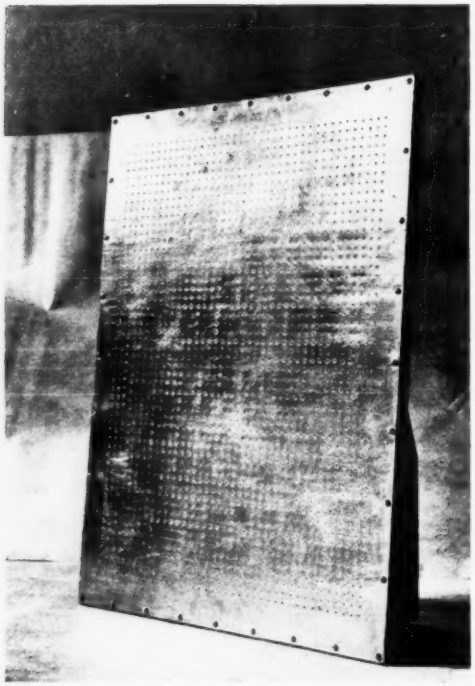

Fig. 5. Surface of pelvimeter as used by Thoms showing numerous perforations.

Fig. 6. Surface of pelvimeter as used by author. Arrows point to the two small holes which form the scale.

As stated earlier in this article many methods have been evolved for doing roentgen pelvimetry, some of them very practical and easily performed, others quite technical and involving considerable time and mathematics. I will endeavor briefly to describe a few procedures which seem to be adapted, due to their character, to the use of most any physician. I do not wish to infer that there are not many other good methods, but I have chosen these few primarily because of their practicability. They are all recently evolved procedures, and the methods are based on principles described by many of the early workers.

METHOD OF HOOTON

Hooton of England has recently described a purely mathematical procedure which he evolved about a year ago. It is one of the most unique methods I know, depending entirely upon mathematics.

The procedure is as follows: Anterior posterior and lateral films are taken of the pelvic region. The anterior posterior film is centered one and one half inches above the os pubis. The lateral film is centered just ahead of the great trochanter. Double screens are used as is also a Bucky diaphragm. The focal film distance is 28 inches. Measurements are taken on the patient which show the distance of the superior part of the os pubis to the table and the width across the trochanters. Measurements taken on the films are the transverse diameter on the anterior posterior film and the distance from the pubis to the sacral promontory on the lateral film.

In order to work out this formula he allows *a* to represent the distance of the os pubis to the table or the thickness of the patient; *b*, to represent the width of the patient across the trochanters; *c*, to represent the focal film distance; *d*, to represent the transverse diameter of inlet on the anterior posterior film; *e*, to represent the conjugate diameter recorded on the lateral film.

The formulas are as follows:—

The true transverse diameter equals $\frac{d \times (c - a)}{c}$

The true conjugate diameter equals $\frac{e \times (c - a)}{c}$

The measurements are all easily made, like the application of the formula and the ma-

matics are simple. The author claims that tests on a skeleton show an accuracy to within $^1/_{12}$ of an inch.

METHOD OF ROWDEN

Rowden, also of England, about a year ago described a very simple and practical method that he has devised. It is of the scale type and the procedure is as follows: The first work necessary in carrying out this method is to construct a set of scales such as are shown in Figure 1. To do this he takes a strip of lead 12 inches long and 2 inches wide. Holes are drilled down the center of this strip of lead the distance between these holes being one-half inch. This scale is covered with plywood to keep it from bending. The rule is then placed 4¾ inches above the Bucky diaphragm and parallel with its surface. A film in a cassette is inserted into the Bucky and an exposure made at a focal film distance of 4 feet, 6 inches. The film is removed and another inserted in the cassette which is placed in the Bucky again. The rule is then moved to an elevation of 5 inches and another exposure taken. This procedure is repeated, each time raising the rule ¼ inch, until the maximum height necessary is reached. These films are then developed and many printed scales made from each one of them. All scales are marked at the height at which they were made.

The patient is then placed on the Bucky diaphragm in a semi-upright position. The pelvis is centered over the Bucky by the use of a plumb line. The tilt of the back is adjusted so that the superior pelvic strait will be parallel to the film.

A roentgenogram is then taken and the height of the symphysis from the Bucky measured which gives the thickness of the patient. The appropriate scale is then chosen according to the height of the symphysis and attached to the roentgenogram and all measurements on this film are then made by using this individual scale (Fig. 2).

The author claims a method of testing the accuracy of the procedure and states that it is accurate within ⅛ of an inch.

The method is certainly very simple and can be duplicated with very little effort. The only suggestion one might make regarding the procedure is that since the scales take care of the distortion, the focal point might be shortened to cut down the time of exposure.

Rowden also uses a very practical method of "shading" the pubic region with a thin piece of lead which is placed over the symphysis after part of the exposure is made. This prevents the common over exposure of the pubic region and the under exposure of the sacral region and gives more even detail to the superior pelvic strait.

Fig. 7. Semi-recumbent position for taking pelvigrams as used by the author.

METHOD OF WALTON

Walton, of Baltimore, a little over a year ago, described a very fine practical procedure of the scale type.

The basis of the method is a graph of a distorted scale (Fig. 3). The scale is made by taking exposures of a lead rule perforated in centimeters. At each exposure the scale is raised 1 centimeter and the exposures are made at heights varying from 1 to 40 centimeters. A focal film distance of 30 inches is used. The graph is made by using cross lines 1 centimeter apart and running up to 40 centimeters. The distortion of each centimeter is marked on the corresponding line which represents the height at which the scale was taken. These are marked all the way up the height of the 40 centimeters and each dot is connected by a line running up and down as seen in the figures. This gives the amount of distortion for each centimeter at each height taken. The patient is placed over a Bucky diaphragm in a semi-reclining position, the pelvic inlet being brought parallel to the film. After exposure is made the height of the symphysis is measured from the film and not from the top of the Bucky. This measurement corresponds with the original method of making the scale.

The anterior posterior, oblique and transverse measurements are taken on the film with calipers and then compared to the chart or graph at the height found in the patient. The corrected measurement is then recorded.

When the method is used for taking cranial measurements, the patient lies flat on her back over the Bucky. The position of the child's head

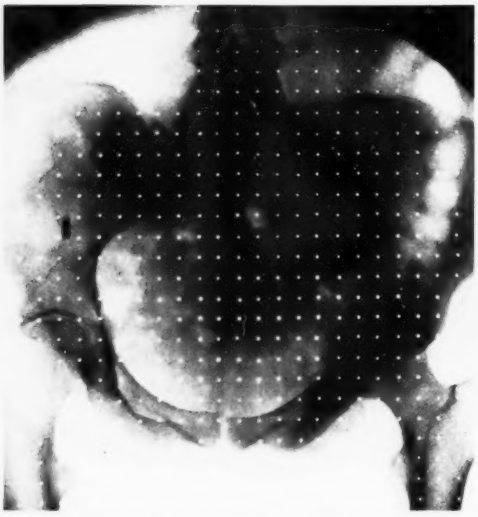

Fig. 8. Type of scale superimposed on film by pelvimeter as used by Thoms. Pelvic measurements are made by counting spaces made by dots between points to be measured.

Fig. 9. Type of scale superimposed on film by pelvimeter designed by author. Note two small dots.

is located and a mark placed on the mother's abdomen at a point above the center of the child's head. A mark is also placed on the lateral abdominal wall opposite the center of the child's head. The distance of the center of the child's head from the film in the plane at which the measurements are to be taken must be known.

The first exposure is made above the center of the child's head at a thirty inch focal film distance. The second exposure is made lateral over the lateral mark on the mother's abdomen at a focal film distance of thirty inches. The fronto-occipital and biparietal diameters are measured with calipers on the film and the corrected measurements are made on the chart.

METHOD OF THOMS

Thoms (32, 33) of New Haven, Connecticut, has done a large amount of work on roentgen pelvimetry over a period of some years. His contributions to the subject have been many, and throughout the course of his work he has always adhered to procedures which have been practical and which are classified as scale methods. The scale he has been using for the last few years consists of a lead plate, the entire surface of which is perforated with small holes (Fig. 5). These holes are placed at the intersection of lines running horizontal and vertical which are 1 centimeter from each other. When this scale is reproduced on the film it causes the film to be covered with small dots which are an equal distance apart and the spaces between which are distorted in proportion to the distance that the scale is removed from the film.

The procedure of Thoms is as follows: A small piece of adhesive is placed over the spine at the region of the junction of the fourth and fifth lumbar vertebræ. The patient is placed over the film in a semi-recumbent position. In the work of Thoms, I see no mention of him using a Bucky diaphragm and it is my opinion that he uses none. The tube is centered over the pelvis about 5 centimeters posterior to the symphysis. A plumb line is dropped from the frame of the tube holder to the top of a symphysis and this gives the location of that region. The distance of the adhesive tab on the back to the film is measured with calipers. A straight line drawn through the adhesive tab and the tip of the plumb line passes through the plane of the pelvic inlet.

An exposure is now made and the patient is then removed from the table. The lead scale is then placed in the plane of the pelvic strait which previously was located by the height of the adhesive tab from the film and the tip of the plumb line. A short exposure is now made which imprints the scale (Fig. 8) on the film. It is not necessary for the pelvic strait to be parallel with the film in this procedure, but for accuracy is lo-

Fig. 10. Flexible ruler with centimeter scale used for making measurements by author's method.

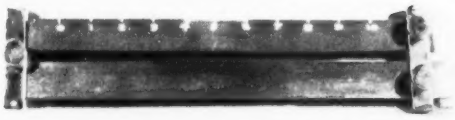

Fig. 11. Flexible ruler extended showing distorted scale. Each centimeter distorted an equal and proportionate amount.

cating the sacral promontory it should be nearly so. The corrected measurements are made by reading the number of spaces between dots connecting the points desired to be measured. This gives the various diameters directly in centimeters.

The procedure for cephalometry is similar, the scale being superimposed in the same plane as the region of the head to be measured.

The method is very practical and logical. There is nothing in the procedure but what can be duplicated by a physician or radiologist with average equipment and average ability.

METHOD OF AUTHOR

In the method I have just recently devised and which I am using at the present time, the procedure is similar to that of Thoms in that a sheet lead scale is superimposed in the plane of the pelvic strait. The variation comes, however, in the type of scale used and the method of making the measurements. The procedure is as follows:

A point on the spine at the upper border of the fifth lumbar vertebra, which point was referred to by Albert in 1899, is located and a small piece of adhesive placed over this region. A line drawn from that point through the superior border of the symphysis pubis passes through the plane of the inlet of the pelvis. This method of locating the plane of the superior strait was described by Albert in his first article written in 1899 and has been used ever since by all workers whose methods have necessitated the locating of the plane of the superior strait.

The patient is placed in a semi-recumbent position (Fig. 7.) with the pelvis centered over the cross lines on the surface of the Bucky diaphragm. By the use of calipers the distance from the adhesive tab to the Bucky is determined. By using a ruler the distance from the superior surface of the symphysis to the Bucky is measured. The patient is adjusted so that these two measurements correspond. This places the plane of the inlet in a position parallel to the film. For the correct location of the inner border of the superior point of the symphysis and the correct location of the sacral promontory, it is my opinion that this is the correct position. Where the strait of the pelvis is not placed parallel to the film I believe that for the correct location of the sacral promontory, stereoscopic films should be taken.

The tube is now centered to correspond with the cross lines of the Bucky at a focal film distance of 30 inches. An exposure is made of the pelvis. The patient is then removed from the table and the lead scale placed in the same plane as the pelvic inlet. This is accomplished by using the measurements previously mentioned and with the Bucky running a short exposure is now made which superimposes the scale on the film.

If the patient is one with known deformed, generally contracted or justominor pelvis or if one wishes to vary the technique by not having the plane of the pelvis parallel to the film, the procedure then varies and stereoscopic roentgenograms are taken of the pelvis instead of a flat film. The scale in this latter instance is superimposed on one of the stereoscopic films. The reason for adopting this method is that the stereoscopic roentgenograms gives one a better visualization of the pelvic inlet, makes the parts desired to be measured more distinct, and gives one a better localization of these points. This is a considerable help in cases as already mentioned.

The pelvimeter consists of a lead sheet approximately 16 by 19 inches in size. This sheet of lead is 1/16 of an inch thick and held firmly to a board of the same dimensions by screws placed around the border of the lead plate. The board is approximately ½ inch thick and made of basswood. Stiles are placed across each end of the board to prevent warping. Legs are mounted on the board and by the use of thumb screws the pelvimeter can be lowered or raised (Fig. 4).

On the surface of the lead sheet a line running in the longitudinal center of the plate intersects a transverse line at right angles, at the center of the plate. By the use of a small sewing needle two holes ten centimeters apart were made in the former line and equidistant from the intersection with the latter line (Fig. 6). When an exposure of this scale is made on the film two small dots in the

region of the pelvic inlet are reproduced on the film (Fig. 9).

In an article recently published Moore and Skinner proved that when a perforated lead plate such as Thoms uses is placed between the focal point of an X-ray tube and a film, with the position of the lead plate parallel to the film, the space between the dots reproduced on the film when an exposure is made, will all be equally distorted and the space between the dots would be the same whether near the center of the film or near the periphery. Therefore, the space between two dots 1 centimeter apart is distorted on the film the same amount regardless of where they appear on the film. Also the space between any two points 10 centimeters apart on the scale would be distorted on the film a proportionate and equal amount to all dots on a scale 10 centimeters apart. Then each centimeter of the 10 centimeter scale would be distorted an equal amount and would not necessarily have to be represented by a dot on the film. Therefore, the two dots on the film represent the proportionate distortion for all measurements made on that particular film.

To complete the procedure then and make the measurements, it is only necessary to have a ruler that can be distorted in the same proportion that the two dots on the film are distorted. This has been accomplished by making a ruler out of flexible and uniform rubber. A normal centimeter scale 10 centimeters long is printed on the rubber ruler. A frame is constructed to hold firmly the rubber ruler, one end of which is movable and can be extended to any desired distance and held in position by a thumb screw (Fig. 10).

When it is desired to take measurements of the pelvic inlet on a certain film all that is necessary is to extend the ruler until the zero mark and the 10 centimeter mark are the same distance apart as the two dots on the film. Then one has an equally distorted ruler on which each centimeter is distorted an equal amount and the pelvic measurements can be made directly on the film as one would make measurements with a ruler (Fig. 11).

The value of this procedure is in its simplicity as well as its accuracy. The fact that only two dots are necessary makes the construction of the pelvimeter very accurate and easy. The making of the pelvic measurements on the X-ray films by the use of a ruler is certainly simplicity itself. In cephalometry the scale is superimposed in the same plane as the region of the head to be measured.

CONCLUSIONS

Accurate pelvimetry is a valuable diagnostic procedure in obstetrics.

Roentgen pelvimetry is gradually superseding manual and instrumental pelvimetry due chiefly to the fact that it is a much more accurate procedure.

There are many good methods of roentgen pelvimetry in use at the present time, many of which are simple and practical enough for the use of any obstetrician.

The value of roentgen pelvimetry as a diagnostic measure in obstetrics is dependent upon simple and practical methods in the hands of many rather than complicated procedures in the hands of a few.

Any good recognized metho[d] is accurate enough for all practical purposes.

Cephalometry is a valuable adjunct to pelvimetry in the study of disproportion in certain cases.

Recommended routine would be as follows:

1. Roentgen pelvimetry on all primiparæ as soon as pregnancy is diagnosed.
2. Roentgen pelvimetry on all multiparæ with history of difficult labors.
3. Routine care and diet by obstetrician in all cases where small pelvic inlets or distorted pelvis is found.
4. Roentgenogram of all obstetrical cases just prior to term.
5. If latter procedure shows any evidence of disproportion, cephalometry should be resorted to.

If this routine is adhered to there should be some manifest reduction in mortality in obstetrics.

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INTRARENAL AND PERIRENAL LIPOMATA

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LIPOMATA or fatty tissue tumors have well defined, gross, microscopic and chemical characteristics. They are subject to secondary degenerative changes in advanced growth and are frequently found in combination with other connective tissues and are then classified as fibrolipomata, myxolipomata, chondrolipomata, and so forth. The lipomata are of clinical significance because: (1) the larger lipomata produce serious pressure effects on adjacent structures; (2) large lipomata have caused emaciation by diverting nutrition from the body (Wells); (3) multiple lipomata may occur, a condition noted by Virchow, in which hundreds of lipomata throughout the body are found in such organs as the lungs, liver, and other tissues where fat normally is absent; and (4) sarcomatous transformation may appear, and recurrence after removal is not infrequent and is sometimes evidence of this malignant change.

The etiology of these growths is unknown, but various hypotheses have been advanced to explain their origin. The general etiological classification of lipoma and lipomatoid processes of Ewing is as follows: (1) obesity; (2) localized overgrowth of fat tissue; as, for example, the so-called fatty neck or lipoma annulare colli; (3) replacement lipomatosis, seen in atrophic organs, for example, the kidney and lymph nodes; (4) homologous lipoma, for example, the solitary subcutaneous lipomata; (5) heterologous lipoma, for example, intrarenal lipoma, and (6) overgrowth lipomata, consisting of the mixed tumors and teratomata. Other conditions which have been suggested as possible etiological factors are: hereditary influences, congenital predisposition, disturbances in thyroid and pituitaryglands,alcoholism,trauma,inflammation.

Heterologous lipomata may arise in the kidney, as stated by Alsberg, from misplaced groups of embryonal tissue cells from the fat capsule, which become enclosed in the parenchyma of the kidney in the process of development. Warthin, on the other hand, stated his belief that fatty metamorphosis occurs and that the lipomata arise from the connective tissue of the kidney by transformation of fibroblasts into fat cells.

Grawitz pointed out the existence of true intrarenal lipoma. He believed that they were rare, and he emphasized the importance of distinguishing them from the larger group of renal neoplasms with high fat content, but which microscopically simulated suprarenal tissue. To this latter group he applied the term hypernephroma.

Intrarenal lipomata differ from pararenal lipomata by taking origin from tissue in which fat normally is absent. In the literature two varieties of intrarenal lipomata have been described; the most common are small, circumscribed single or multiple, either pure or mixed, and less common is the so-called "replacement lipomatosis" form noted by Askanazy. To our mind this type does not belong in the group of lipomata because it does not represent pure tumor, but rather fatty replacement which in the kidney is associated with atrophy, infection and the formation of calculus. The same pathological process is observed in many other parenchymatous organs undergoing atrophic degenerative changes.

The perirenal lipomata take origin from the perinephric fat and contain, as a rule, more connective tissue. Areas with accumulation of mucinous fluid are often seen, and sarcomatous change is not infrequent. Their growth, ordinarily slow, may progress rapidly with malignant change, and recurrence after operative treatment is not unusual. As the perirenal lipoma advances in growth and attains large size, it encroaches on the peritoneal cavity by elevating the posterior parietal sheath, and is then classified simply as a retroperitoneal lipoma, the anatomical distinction from lipomata originating from adjacent adipose structures often being impossible.

REVIEW OF LITERATURE

The literature in general consists of single case reports or small series of cases. A few writers have published larger reviews of the subject. Von Wahlendorf, for example, reviewed 165 cases of retroperitoneal lipoma of all types: 70 cases (46 per cent) were pure lipomata, and 83 (54 per cent) were mixed. Of this latter group, 31 (20 per cent) were fibrolipomata, 16 (10 per cent) myxolipomata, 15 (10 per cent) fibromyxolipomata, and in 21 (14 per cent) there was sarcomatous change.

Retroperitoneal lipoma occurred most commonly in the fourth decade, although one case

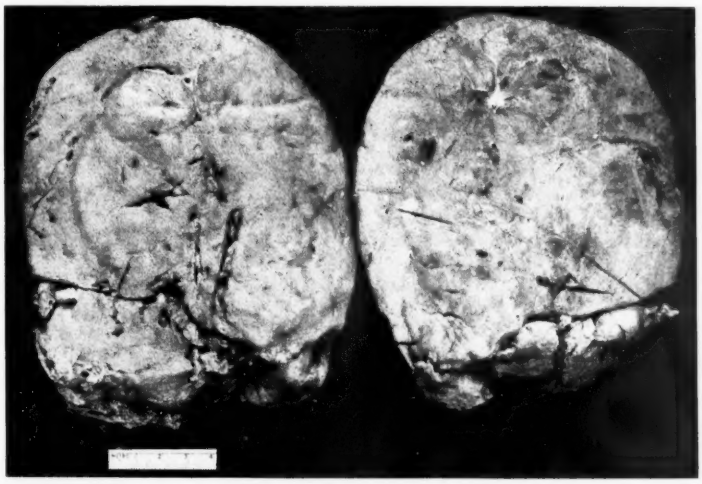

Fig. 1. Specimen showing the cut surface.

found in the first year of life and one in the eighth. One hundred six patients (72 per cent) were females, and 42 (28 per cent) were males. In 132 cases in which the site was definitely recorded, it was in the abdomen in 104 cases (79 per cent) and in the pelvis in 28 (21 per cent). From the pathologico-anatomical standpoint, 30 cases (23 per cent) were limited to the capsule of the kidney, and 46 cases (23 per cent) involved the perirenal and lumbar fat. In von Wahlendorf's opinion, the myxoma represents a transitional form between benign and malignant.

Albarran and Imbert in a total of 54 retroperitoneal tumors, found 22 lipomata, 6 lipomyxomata, 12 fibromyxolipomata, 1 myxoma, and 17 with sarcomatous change. Adami recorded 42 cases of lipoma of the retroperitoneal tissue in general; a third of them originated around the kidneys.

Le Fur cited 122 cases, 110 of which had been reviewed by Thevenot, and they overlap to some extent those reviewed by von Wahlendorf. The remainder were additional cases reviewed by him since the war. Lecène, in 33 cases found an incidence of 70 per cent in females and 30 per cent in males. The average age was from 40 to 50 years, but there was 1 case in the first year and 1 in the seventh decade. The incidence of occurrence on both sides of the body was equal. Only in the smaller tumors could the point of origin be determined with any degree of certainty. In his series of 33 cases there were 6 lipomata, 4 fibrolipomata, 2 fibromyomata, 3 fibromyxomata, 5 fibrosarcomata, 2 angiosarcomata, and two mixed tumors.

Elansky, in a study of the so-called replacement lipomatosis or renal atrophy with fat substitution, found the total number of cases of perirenal lipomata reported in the literature as approximately 150. He quoted Lubarsch as saying that in the 40,000 necropsies at the Berlin Institute from 1897 to 1917, only one case of fatty tumor of the capsule of the kidney was seen.

Because of the rarity of this condition, probably most of the cases encountered have been reported in literature, but in many instances the origin of the tumor, whether from the capsule of the kidney or from the perirenal fat, is not stated. Elansky's case of diffuse fatty replacement of renal tissue is similar to those reported by Dick-

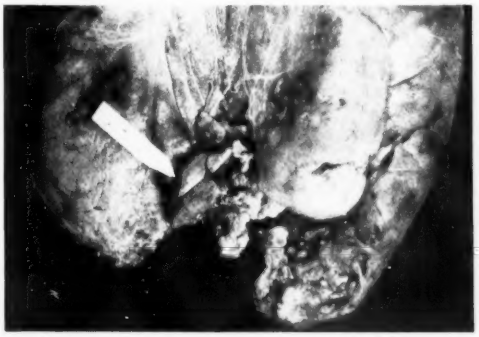

Fig. 2. Specimen showing attachment to the kidney.

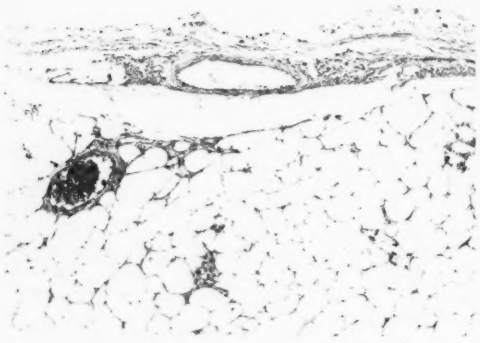

Fig. 3. Specimen showing capsule of tumor and the adult adipose tissue, the structure of which the tumor was mainly composed (low power).

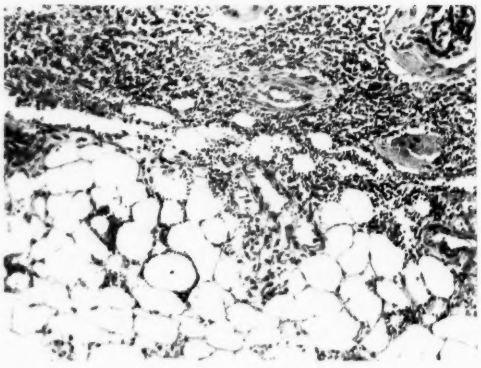

Fig. 5. Specimen showing intimate relation of base of tumor with renal cortex; complete absence of renal capsule may be noted (low power).

inson, Warthin, and others. Rokitansky and Alsberg stated their belief that the condition is primary, but the considerable degree of adhesions, the parenchymatous atrophy and the frequent association with renal calculi speak strongly in favor of an inflammatory basis. Warthin stated that most of the references to lipoma of the kidney found in the older literature do not deal with true lipoma, but with masses of fat surrounding an atrophied kidney, of which the dilated pelvis or ureter contained a calculus. Usually the kidney was completely surrounded by the tumor; hence the capsule was looked on as the origin of the growth. Crabtree stated that perirenal lipomata are more common than intrarenal, but this was not the experience of Hunt and Simon. The latter emphasized the point that perirenal lipomata, if large, are likely to be of more clinical significance.

Smaller series of cases or reports of single cases of especial interest may be found in the papers of Barclay, Lacrampe, Eiselsberg, Alsberg, Warthin, Reynolds and Wadsworth, Hirsch and Wells, Alexander, Samuels, Lower and Belcher, and Crabtree.

Most writers agree that the diagnosis of these tumors is difficult. Symptoms are absent or obscure until the enlargement is sufficient to produce disturbance in adjacent organs by compression. Hence, delay in recognition is usual. The earliest symptoms noted in the literature, when the gastro-intestinal tract has been compressed, have been primarily vague dyspepsia with dull pain in the back, heaviness after meals, vomiting

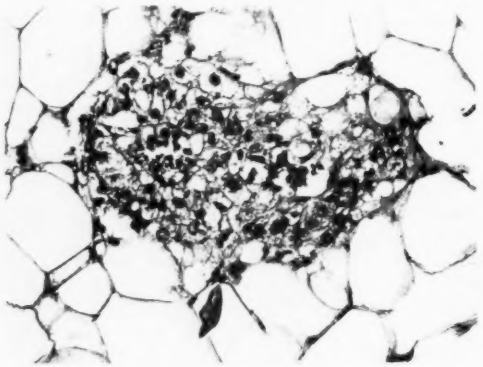

Fig. 4. Specimen showing an island of embryonic fat tissue (high power).

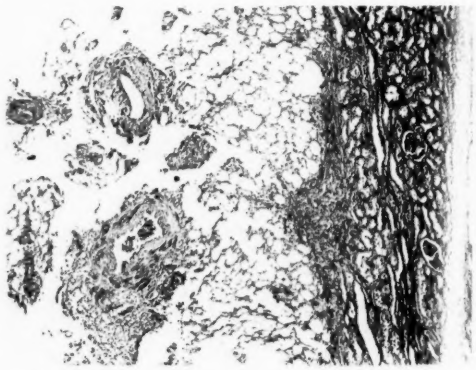

Fig. 6. Specimen showing the large blood vessels in the region of the renal cortex (low power).

diarrhœa, constipation, and in some instances chronic or acute ileus. Pressure on the kidney of the pelvis and ureter have produced hydronephrosis, pyelitis, oliguria, or anuria. The more general symptoms noted were weakness, fatigue, nervousness, and inanition without definite cause. On the objective side, the discovery of an abdominal mass, occupying the retroperitoneal lumbar region, is the most significant single observation. Whether such physical methods as palpation, percussion, and insufflation of the large bowel can be depended on to define the situation of the lesion is open to question. Urological methods should always be invoked in order to implicate or exclude the genito-urinary tract. Exploratory laparotomy should be advised whenever such a tumor is suspected, as the condition is essentially surgical and the diagnosis is rarely made before operation. It is as de Quervain has said: "Jeder Regel spotten die Geschwuelste der Nierenfettkapsel."

The earliest case of retroperitoneal lipoma in which operation was performed was reported by Lizars in 1824. The treatment is surgical and should be as early and as complete as possible. The choice of surgical approach depends chiefly on the size of the tumor; most authors prefer the lumbar route for the smaller tumors because of its lower mortality, and the abdominal route for the larger tumors because of the increased accessibility. Nephrectomy is indicated whenever the kidney is intimately adherent to the tumor. Nephrectomy was required in 138 operations (29), 29.7 per cent. Hartman and Lecène performed nephrectomy in 18 of 27 cases, and de Chamoff removed the kidney in 34 of 46 cases. Extirpation of the tumor by morcellation is occasionally the only means possible, but should be avoided when possible because of the danger of spreading tumor cells of infection and of hæmorrhage. Drainage usually is advocated because of the extensive raw surface left after ablation of large tumors.

In von Wahlendorf's series of 165 cases, 113 came to operation. Twenty-nine patients died during or at the conclusion of the operation, a mortality of 25 per cent. Twenty-one (14 per cent) of the growths were sarcomatous, and 20 per cent of the remainder were considered borderline between benign and malignant. In 60 cases (54 per cent) cure was obtained. Nine patients could not be traced. Albarran and Imbert reported a mortality of 30 per cent in their 54 cases, and Thevenot, in his 110 cases a mortality of 23 per cent, whereas Le Fur, on adding his 12 cases to those of Thevenot, obtained the slightly higher figure of 25 per cent. Recurrence was fairly common. Von Wahlendorf noted recurrence in 15 cases, 14 per cent of his 113 operative cases. In 3 of Le Fur's cases there was recurrence, both local and general, in 2. In each instance in the latter the pathologist had made an unqualified diagnosis of benign lipoma. Consequently Le Fur prefers to consider all pararenal tumors as malignant and to extirpate as widely as possible in order to diminish the risk of recurrence.

From summarizing the literature we conclude: (1) the etiology is unknown; (2) the condition is more common among women; (3) the diagnosis is difficult and before operation almost impossible; (4) the treatment is surgical; (5) the operative mortality is fairly high; and (6) malignant change and recurrence are fairly common.

REVIEW OF DATA CONCERNING CASES IN THE MAYO CLINIC

At The Mayo Clinic, Masson and Horgan reported 12 cases of retroperitoneal lipomata. Mayo and Dixon, and Hunt and Simon reported 3 cases and 2 cases, respectively.

We reviewed the 314 case records of retroperitoneal tumors observed in the clinic between the years 1910 and 1930, and in 42 of these retroperitoneal lipomata were recorded. Forty tumors were extrarenal and 2 were intrarenal. Nineteen patients were men and 23 were women. The youngest was aged 28 years and the oldest 68. The average age was 49.3 years. The average duration of symptoms was 5.8 years, the shortest being 3 weeks and the longest 20 years. A diagnosis of retroperitoneal tumor was suggested in only 5 cases. In 21 cases the pre-operative diagnosis was incorrect and in 14 the patient came to operation with a diagnosis of unclassified abdominal tumor. In 2 cases a diagnosis was based on a pathological report made subsequent to operation elsewhere.

The complaint of enlarging abdomen or the discovery of a mass by the patient was most common and occurred in 28 of the 42 cases. Abdominal pain or discomfort was noted in 20 cases, dyspepsia in 11, loss of weight, strength, and appetite in 11, constipation or diarrhœa in 8, nausea and vomiting in 4, and swollen testis in 1 case. Examination disclosed a palpable mass in all but 1 case. In 7 cases the mass was on the right side and in 14 it was on the left. In 5 cases the entire abdomen seemed filled with the tumor, and in 2 the mass was in the umbilical region. The upper part of the abdomen was involved by a mass in 1 case, and the lower part in 2 cases. There was little of diagnostic import in the laboratory data. Urological examination was made in 12 cases.

In 9 cases the mass was diagnosed as extrarenal. In 2 cases the diagnosis of renal tumor was made correctly, and in 1 case the diagnosis of renal tumor was disproved at operation.

In all but 4 cases a transperitoneal approach was employed. In these 4 the usual incision in the loin for nephrectomy was used. Nephrectomy was performed six times. At operation the situation and attachments of these tumors were found to be as follows: in the right upper quadrant in 1 case, in the right side in 4 cases, in the right renal fossa in 7 cases, in the left upper quadrant in 1 case, in the left lower quadrant in 2 cases, in the left side in 5 cases, in the left renal fossa in 11 cases, in the entire abdomen in 2 cases, in the upper part of the abdomen in 1 case, in the lower part of the abdomen in 1, in the mesentery of the small or large bowel in 9 cases, in the pelvis in 3 cases, in the right kidney in 1 case and in the left kidney in 1 case. In 21 cases the tumor was thought to have been removed in its entirety, and in 13 it was possible to remove a portion only. In 9 cases a small piece of tissue was taken for diagnosis.

The largest specimen removed was a fibromyxolipoma which weighed 47 pounds. In 35 cases the tumor was single, and in 7 the tumors were multiple. The total number of tumors reported on was 61. Of these there were 21 lipomata, 6 fibrolipomata, 4 myxolipomata, 7 fibromyxolipomata, 1 myxoliposarcoma, 4 fibromyxoliposarcomata, 1 fibroliposarcoma, and 11 lipomata with sarcomatous change. Therefore, 44 were apparently benign and 17 were definitely malignant. Infection or degenerative changes appeared in nine of the lipomata.

Of the 42 patients, 8 are living and well, the shortest 9 months and the longest 4 years since operation (average 2.3 years). Two other patients are living, but have had a recurrence of symptoms 2 and 4 years after operation. Eight patients died in the hospital, 4 of bronchopneumonia, 2 of peritonitis, and 2 of shock and hæmorrhage. Seventeen patients have died since operation, varying from 2 months to 4.5 years, and 7 could not be traced. Of 8 patients whose condition was malignant at the time of operation, 6 are known to be dead; 1 patient is living and well 5 months after operation, and 1 could not be traced. Twelve patients had recurrence. Six of these had manifested malignant change at the first operation and of these 5 are dead and 1 is living 10 months later. Six patients had recurrences; there had been no evidence of malignant change at the first operation, and of these 5 are dead and 1 is living 3 years later. One of these patients was operated on four times and one three times for recurrence.

In addition there were 14 cases in which intrarenal lipomata were found at postmortem examinations. These growths usually were small, cortical, or subcapsular fatty nodules of no clinical significance.

Comparison of our data with those in the literature shows in general fairly close agreement. It will be noted that the condition is more common among women, that the diagnosis is seldom made before operation, that operative mortality is high (19 per cent in our series), and that recurrence is fairly common (14 per cent in our series of benign lipomata and a total of 28.5 per cent in cases showing malignant change at the time of the first operation).

The following report of a case is of interest because of the pararenal anatomical position of the growth and its probable intrarenal origin.

A woman, aged 36 years, came to The Mayo Clinic September 14, 1931, complaining of intermittent attacks of diarrhœa, occasionally with generalized abdominal cramps, of 12 years' duration. The attacks occurred about once a month and lasted 1 or 2 days. Blood or mucus had not been noted in the stools. Her general health otherwise was good. The appendix and a cystic right ovary had been removed elsewhere, and splenectomy had been advised.

General examination was essentially negative, except for a tumor in the left upper quadrant of the abdomen. The mass, although not altogether typical of a spleen, still had more characteristics of an enlarged spleen than of a kidney or a retroperitoneal tumor. Urinalysis was negative. The concentration of hæmoglobin was 72 per cent, erythrocytes numbered 4,510,000, and leucocytes 8,800 in each cubic millimeter of blood. The patient presented intravenous urograms made elsewhere which apparently excluded the kidneys.

A diagnosis of tumor of the left side of the abdomen was made, with splenomegaly as the most probable pathological condition and retroperitoneal tumor as the second. September 23, 1931, the patient was operated on through a left rectus incision. A large retroperitoneal tumor was encountered. When the posterior sheath of the peritoneum was opened, the tumor was brought into view. It was definitely encapsulated, about 15 or 20 centimeters in diameter, fairly movable, irregularly oval, and yellowish. The mass separated readily with minimal bleeding from adjacent structures except at its attachment in the lower pole of the left kidney. Here, because of its firm attachment to the kidney, it was deemed best to remove the tip of the lower pole of the kidney with the tumor. On palpation of the vessels in the pedicle of the kidney, it seemed as if the blood supply were greater than usual. The retroperitoneal space was then drained through a separate incision in the left loin. General abdominal exploration gave negative results. The patient had an uneventful convalescence and was dismissed from the clinic October 13, 1931, in good general condition.

The pathologist described the specimen as a pure retroperitoneal lipoma weighing 850 grams and measuring 15 by 12 by 12 centimeters, with a small portion of the kidney. Grossly the tumor was a smooth, soft, light yellow, ovoid encapsulated body. Cut section revealed very little fibrous

tissue and no large blood vessels (Fig. 1). At its upper end it was attached to the tip of the lower pole of the kidney (Fig. 2). The renal capsule stripped freely except at this point of attachment. Several sections were cut from this site and stained with hæmatoxylin and eosin for microscopic study. Sections were also taken from other portions of the tumor. These showed that the tumor was composed mainly of adult adipose connective tissue (Fig. 3) with here and there small islands of cells having a stainable cytoplasm, small, densely stained nuclei, and a variable number of lipoid droplets (Fig. 4). These cells conformed in morphology and staining reactions with embryonic types of fat cells. Connective tissue was scanty and when present was arranged around blood vessels. In the sections taken through the site of the attachment of kidney to tumor, the areas suggesting embryonic fat cells were more numerous (Fig. 5), but the most striking feature was the presence of large blood vessels in the tumor adjacent to the parenchyma of the kidney (Fig. 6), strongly confirming the supposition that at least a goodly portion of the blood supply to the tumor came directly from the blood vessels of the renal cortex. The tumor was also in direct continuity with the cells of the renal cortex, the capsule at this point being absent and on the margin being reflected up over the tumor. These facts lead us to conclude that we were dealing with a true intrarenal lipoma, in spite of its gross anatomical pararenal situation.

In the interest of accurate pathological classification we suggest that tumors of this type shall be subjected to careful histological study. It is possible that some of the cases in the literature reported as perirenal lipoma are actually, as in this case, intrarenal, at least in origin. In this connection the observation of increased vascularity of the renal pedicle made at the time of operation is of particular interest.

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THE ADMINISTRATION OF PROCTOCLYSTERS

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REQUESTS have been made from time to time for information as to the best methods for the administration of proctoclysters. It would seem that of all hospital procedures designed to aid the patients in a time of acute need, this is the most slighted and neglected. John B. Murphy, in his dissertation on peritonitis in 1908, describes a method of administering fluids per rectum, which cannot be improved upon to this day. Some difference of opinion may be expressed on the duration of such administrations of fluids as well as in the choice of fluid used but the procedure is certainly excellent. We are all familiar with the sight which greets us on entering the room of the patient receiving proctoclysis. There is the vacuum flask perched on the uppermost rung of a stand with fluid running into the patient 40 to 60 drops a minute, without the slightest regard as to whether the patient is absorbing the fluid at the rate at which the drip is set. Soon we see that the patient has soiled his linen and is complaining of great distress. The nurse complains that nothing can be done with the patient. (A glance on the inside of the tube would probably show that the pressure was 15 to 25 inches of water pressure). The attending surgeon then loses patience with the method and orders hypodermoclysis. Allow me to quote an excerpt from Murphy's original paper on the subject. "The fluid should be administered through a fountain syringe to which is attached a three-eighths inch rubber hose fitted with a hard rubber or glass vaginal douche tip with multiple openings. This tube should be flexed to almost right angles 3 inches from its tip. A straight tube must not be used as the tip produces pressure on the posterior wall of the rectum when the patient is in Fowler's position. The tube is inserted into the rectum to the flexion angle and secured in place by adhesive strips binding it to the side of the thigh so that it cannot come out; the rubber tubing is passed under the bedding to the head or foot of the bed, to which the fountain is attached. It should be suspended from 6 to 14 inches above the level of the buttocks and raised or lowered to just overbalance hydrostatically the intra-abdominal pressure, i.e., it must be just high enough to require 40 to 60 minutes for 1½ pints to flow in, the usual quantity given every 2 hours. The flow must be controlled by gravity alone and never by a forceps or constriction on the tube, so that when the patient endeavors to void flatus or strains, the fluid can rapidly flow back into the can, otherwise it will be discharged into the bed. It is this ease of flow to and from the bowel that insures against overdistention and expulsion onto the linen. The fountain had better be a glass or graded can so that the flow can be estimated. The temperature of the water in the fountain can be maintained at 100 degrees by incasement in hot water bags (or by partial immersion of an electric light globe). The fountain is refilled every 2 hours with 1½ to 2 pints of solution. The tube should not be removed from the rectum for 2 or 3 days. When the nurse complains that the solution is not being retained, it is certain that it is not being properly given; even children retain proctoclysis surprisingly well."

McClanahan, in his modification of Murphy's method, uses merely an irrigating can and a rectal tube with the end cut off. The can rests on a table beside the patient's bed which is on a level with the patient's rectum. Care is taken that the level of the fluid in the can is at no time more than 4 inches above the level of the rectum. The rectal tube extends from the can, under the bed clothes, into the patient's rectum. It is not necessary to regulate the flow because a constant to and fro movement is maintained between the bowel and the can.

The great disadvantage to any arrangement such as Murphy and McClanahan describe is that the nurse is required to maintain the fluid level of the solution used, to obtain the best results. It cannot be too strongly stressed that herein lies the success or failure of proctoclysis in any given case.

Recently there has appeared on the market a clyster can with a vacuum container and a visualizer tube on the outside, which enables one to see the level of the fluid within the reservoir. It is the writer's practice to suspend this device at such a height that the visible level of the fluid in the can is about 4 to 8 inches above the patient's rectum. The clyster can is suspended from a stand which may be raised or lowered by means of a crank. Every half hour or so the can is raised to maintain the original pressure if the patient is absorbing the fluid readily.

The preliminary treatment to proctoclysis must always include a thorough emptying of the

bowel by means of an enema. This is done practically routinely in all the hospitals as a pre-operative measure.

The introduction of fluid within the bowel is accomplished by means of the largest size catheter possible to obtain, which is pushed about 6 inches within the anal ring. The fluid of choice is a 1 per cent glucose solution, which is very readily absorbed and non-irritant.

The maintenance of the temperature of the clyster solution is not of the greatest importance in this type of administration of fluids because the amount of fresh fluid introduced into the bowel at any one time is very small. Thus even at a rate of flow of 10 cubic centimeters per minute into an original volume, in the bowel, of 200 to 300 cubic centimeters, the temperature change is small. However, the solution must be at body temperature when first administered.

The clysis is run in 4 hour periods with a 2 hour rest period in between. At the end of the 2 hour rest period following two courses of clysis, it is customary to give the patient a 1-2-3 enema for cleansing purposes. Thus accumulated fæcal material and flatus which has not been expelled through the solution may be removed. Such administration of fluid may be carried on indefinitely without the slightest distress to patient.

We have observed from time to time that the fluid does not readily enter the rectum at the beginning of the procedure. The difficulty may be overcome by lowering and raising the reservoir 15 to 25 inches above the level of the rectum several times. The increased pressure causes the walls of the bowel to fall away from their close approximation. The can is then set at the level at which the fluid just begins to flow into the bowel (4 to 8 inches).

If it is necessary to make use of the type of vacuum bottle which employs a drip visualizer, the midpoint of the latter may be set at the required height above the rectum and the level observed when the tube is filled, may be maintained. If desired a very simple device may be employed which gives excellent results. A glass percolator may be used for the actual administration of the clyster and the vacuum bottle with the drip visualizer, may be utilized to maintain the level in the former. The end of the tube from the visualizer is run under the surface of the fluid in the percolator so that warm solution is constantly coming in. The opening in the top of the percolator may be lightly wadded with cotton, and the level of the fluid is maintained at 4 to 8 inches above that of the rectum.

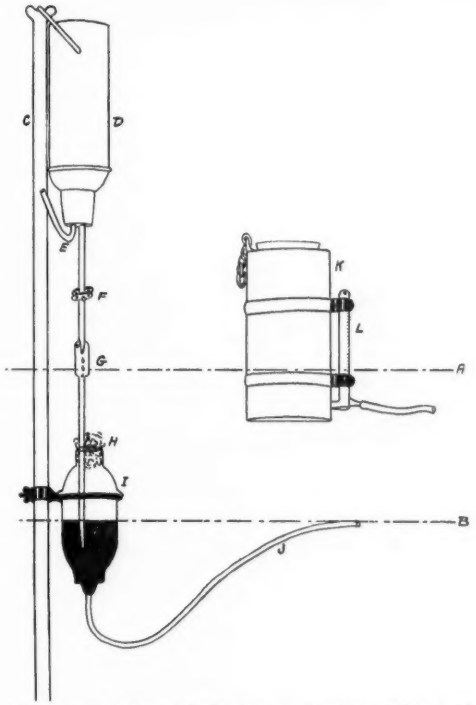

Fig. 1. The line *A* indicates the level at which fluid must be maintained in the reservoirs *D* or *K*, when either of these is used alone. This level is 4 to 8 inches above the patient's rectum. The line *B* indicates the level of the fluid in apparatus *I* when used in connection with *D*. *C* is the stand, *E* an air vent, *F* a screw clamp, *G* a drop visualizer, *H* cotton wadding, *J* tube to patient's anus, *L* visualizer tube of *K*. The level in *I* is also 4 to 8 inches above the rectum.

The following rules governing the use of proctoclysis are suggested:

1. Be sure that the pressure employed is just sufficient to overcome the intra-abdominal pressure (4 to 8 inches).

2. Be sure that the solution used is non-irritant and readily absorbed. (A 1 per cent glucose solution is excellent for the purpose.)

3. Be sure that the patient's bowel is cleansed at regular intervals.

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EDITORIALS

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JANUARY, 1933

THE CLINICAL AS DISTINGUISHED FROM THE LABORATORY EVALUATION OF FACTORS INVOLVED IN HEALING OF INFECTED WOUNDS

IN his book, *Medical Education*, Dr. Abraham Flexner directs our attention to the fact that there is a science of medical practice no less important than the science of the laboratory. This comment appears to apply especially to the treatment of infected wounds. Lessons learned from practice have quite generally been set aside in such cases while technical laboratory methods difficult of clinical application have been brought to the bedside. A field in which this change has given many poor results is that of compound fractures. We are fully aware that reduction of the fracture, accurate maintenance of length and position, and immobilization are essential to good results. In all of the customary antiseptic methods, however, plaster-of-paris casts are barred and splints are disturbed or removed in order that irrigations, fomentations, and such measures may be carried on.

In 1616 Cesare Magati of Scandia published his celebrated work *de Rara Medicatione* in advocacy of an infrequent dressing program for wounds. Magati lacked only the knowledge of infectious organisms and of the modern skeletal fixation devices and plaster of paris for the protection of the wound and the patient to lead him to the position that we are reaching only today.

Belloste, a French military surgeon, adopted the teaching of Magati and gave him full credit (contrary to an Italian notion) for his contribution to surgical practice. John Hunter, in speaking of compound fractures, said "a variety of inventions have been employed to prevent the motion" (of the fragments) "but the dressing of the wound every day counteracts the effect of every invention that has been thought of, and it is perhaps impossible to dress the sore without motion."

Lister's application to surgery of the germ theory of Pasteur was first designed only to exclude infection from the wound. The original Listerian idea was soon changed to a plan of treatment calculated to combat the organisms in the wound. This altered antiseptic program, the many variations of which have had their origin usually in the laboratory, has led us from one excess of antiseptic activity to another until it culminated finally in the Carrel-Dakin method during the war and now in the "viable antiseptic" or maggot treatment. All of these antiseptic methods are open to the objections that they expose healing wounds to trauma and infection, that they disturb traction and immobilizing apparatus which are necessary for all inflamed and injured parts, and that they disregard all

fundamental rules of practice regarding drainage, rest, and protection of the wound and the patient.

During the past ten years a different "method of management" has come to be widely employed; a method in which infrequent dressings have been systematically combined with adequate drainage, with protection of the wound surface against re-infection, injury by instruments, drainage tubes, or chemicals, and with prolonged immobilization of inflamed or injured parts in plaster-of-paris casts.

Statistics have now accumulated to show that by this mode of treatment in osteomyelitis, compound fractures, and other infected wounds, rapid and sound healing is obtained in a high percentage of cases. There is a great reduction in suffering for patients, and substantial economies are effected in labor and hospital costs. Patients leave the hospital in a few days and dressings are done at intervals of weeks or even months instead of daily or oftener as heretofore.

The operative and dressing technique are designed for adequate drainage and the protection of the wound surface by means of a non-absorbent, non-irritating pack with the wound left wide open. No drainage tubes, stitches, or chemicals are employed in the wound, and no postoperative dressings are done for several weeks so that healing may be well established before the wound or the injured or inflamed parts are disturbed in any way.

This, it will be seen, is a clinical rather than a laboratory program. Tests of chemical agents, counts of organisms and their reaction upon each other are disregarded. Inspection and explorations of the wound and the wound area are specifically precluded by the closed cast and entire reliance is placed upon the symptoms of pain, swelling, temperature, leucocytosis, and general appearance of the patient either for satisfaction as to patient's progress or for warnings of complications.

Some laboratory studies already made suggest that alterations in virulence of the organisms after long intervals without change of dressings, the presence of bacteriophage, or the purely physical effect of the petrolatum dressing medium may be of interest in connection with the healing of these wounds. From the purely clinical point of view, however, it appears that the program of protecting the patient by minimal surgical procedures, by guarding the wound surface against trauma, chemical irritants, and infection, and by immobilizing the nervous and vascular parts as well as the bones and joints in correct position for immediate as well as ultimate function, may be the important factors that conduce to recovery. That is, the patient is placed in the best position and the injured and inflamed parts are surrounded by the most favorable conditions for the patient to set up and employ his own processes of repair. What happens in the wound and under the dressing therefore, is of secondary importance to the patient though it may be of great academic and scientific interest to the laboratory technician and the surgeon. The principal forces of clinical scientific interest and of greatest importance to the patient are those operating within himself, and these probably supply all of the active healing agents and principles that appear in and about the wound.

It is a maxim among clinicians that in diagnosis the laboratory and other instrumentalities do not establish, but simply serve to confirm the clinical impressions. Perhaps we should reclaim this point of view for therapy, making sure that the laboratory point of view remains subservient and ancillary to the clinical. Such, at least, appears to

be the lesson which we have learned in the treatment of infected wounds.

H. WINNETT ORR.

PROGRESS AND PROSPECTS OF ROENTGENOLOGIC DIAGNOSIS IN RELATION TO SURGERY AND CLINICAL MEDICINE

LATE in 1895 came Roentgen's announcement of his discovery of roentgen rays, which brought to vision an aid scarcely second to that afforded by the microscope. Then began a stupendous advance in the diagnosis and treatment of disease of man.

At the outset, employment of the roentgen rays in medicine was a separate and special art. Roentgenological examination, with its savor of mechanics, was somewhat beneath the dignity of physicians of the old school, and its early applications were relegated to lay tinkers with electricity or photography and to a few physicians who found pleasure in the study of electric and actinic phenomena. These men were the first roentgenologists. But soon every physician was imbued with the desire to make use of this diagnostic agent which, from all accounts, must be simple to use and probably capable of exhibiting the internal structures of the body as clearly as the furniture in a room can be seen through an open door. Thousands of physicians installed roentgenological equipment. Disillusionment followed speedily. Generating apparatus was capricious, and vacuum tubes were temperamental. To produce a roentgenogram, a tediously long exposure was required. Roentgenograms were disappointing; scarcely more than the outline of the bones could be seen; internal organs and soft tissues cast a confused aggregation of shadows which defied separate identification.

Apparently the game was not worth the candle, and most machines were consigned to the attic. Thus, roentgenology was handed back to its pioneers, who continued faithfully to carry on. Today their names stand out vividly on the medical roster.

About 1910 the efforts of these pioneers began to yield conspicuous results. The medical world awoke to the realization that the roentgen rays were good for something more than to disclose the presence of fractures and foreign bodies. From that period on, roentgenological diagnosis bounded forward. Now, whatever the diagnostic problem may be, roentgenological examination is almost certain to be invoked for its forthright solution, for confirmation of the clinical opinion, or for the revelation or exclusion of hidden complications. Withal, let it be noted well that with few exceptions the achievements and capabilities of roentgenology are due to the efforts of men who have applied themselves persistently and solely to this line of endeavor—roentgenologists.

In view of its progress in the past, there would seem to be little reason for concern as to the future prospects of roentgenology. Nevertheless, most of its practitioners, including those who are not apprehensive as to their personal welfare, regard the general outlook with anxiety, for they are doubtful that the integrity and efficiency of roentgenology will be maintained. In too many instances the roentgenologist apparently is still regarded as a supertechnician rather than as a medical consultant. Too often his work, both technical and interpretive, is subjected to irksome supervision by his clinical and surgical associates. From every quarter he sees invasion of the roentgenological field threatening partition of its domain. Many surgeons, clinicians, and specialists prefer to emply roentgen rays directly, or make their own interpretations, or entrust technicians with diagnostic responsibility, even when competent roent-

genologists who could render better diagnostic service are at hand. As a further affront, many young but thoroughly trained roentgenologists are driven by circumstances to accept full time employment at an extremely modest salary in certain open hospitals which appropriate all profits from the department although professional opinion now effectually bars similar employment of a surgeon, internist, or otolaryngologist. Moreover, by permitting any such practice in the roentgenological department, other specialists may be preparing a like future for themselves.

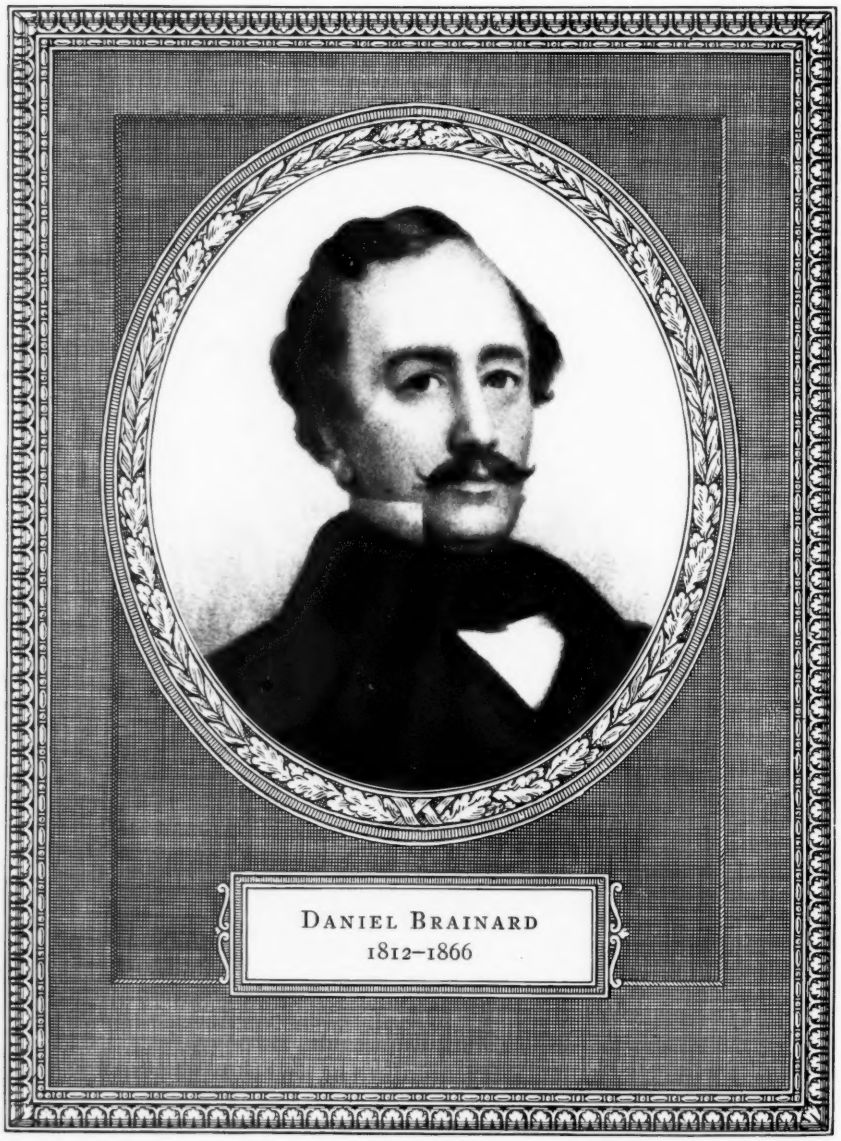
If it be granted that the foregoing conditions are widely prevalent, non-roentgenologists would perhaps offer the following pleas in justification: Roentgenology is not properly a specialty, for it covers virtually the entire field of medicine. To practice it efficiently the roentgenologist would need to be a universal specialist. Its foundations are not only too broad but also too shallow. Roentgenological data alone are not sufficient for diagnosis but must be construed in the light of the clinical facts. With his superior knowledge of these facts, the clinician has an advantage in interpretation. In essence, roentgenological diagnosis is not analytic and rational but empiric and pictorial. Its fundamentals are simple, standardized, widely published, and readily available to all. If equipped with a knowledge of them or with merely an atlas, the clinician should not require expert assistance in diagnosis. In short, the roentgenologist is a superfluous intermediary, for no one can gainsay the right of any physician to use roentgen rays, and he should learn to employ them just as he has learned to use other means to aid his vision.

To all such claims the roentgenologist would oppose an emphatic dissent and might argue as follows: Roentgenology represents a logical division of labor in the evolution and higher organization of medical science and art. It has the same tripartite foundation that underlies all medicine and all specialties in medicine; namely, anatomy, physiology, and pathology. A thorough understanding of these basic sciences as related to roentgenological phenomena is indispensable. Its efficient practice necessitates instruction and experience at least equivalent to those required for the practice of any other specialty. It is not true that clinical data enter primarily and inevitably into roentgenological interpretation, nor is it true that advance acquaintance with the clinical facts in a given case will assist the roentgenologist in the discovery or exclusion of disease. On the contrary, his prime task is a study of anatomy, physiology, and gross pathology as depicted by shadows and shadow-defects, regardless of symptoms and physical signs. His study is not merely pictorial and comparative but highly analytic, and roentgenological advancement has been achieved almost exclusively by this method. Through repeated humiliations he has learned that foreknowledge of clinical facts will bias his judgment and lead him too often into error. In this factor he sees an insuperable obstacle to reliable roentgenological diagnosis by the clinician, and he holds it accountable for a large proportion of current mistakes. He freely admits that clinical facts are often necessary for differential diagnosis, but in such instances he is confident that the best results will follow a review of their respective data by the roentgenologist and clinician in personal conference. For these reasons the roentgenologist feels strongly that to distribute his province among other specialties would be atavistic, degenerative, and a futile repetition of history.

Thus the issue is joined, an issue without rancor or bitterness but none the less an issue. It must be and will be settled without regard for the dignity, fame, or emolument of any

person, group or guild, for the spirit of trades-unionism has no place in it. It would doubtless determine itself in the natural evolution of medicine. If roentgenologists have been remiss in acquiring and maintaining the proficiency rightfully expected of them, if realities are lagging too far behind ideals, or if competent roentgenological diagnosticians are still too few, the condition should be corrected. But whether a proper settlement shall be forwarded or retarded depends not only on the roentgenologists but also on the attitude of the profession of which they are a part. The fact that an issue exists at all is conclusive proof that neither group fully understands the other, and a program of mutual enlightenment should be inaugurated. This done, holding fast to the high purpose of all medical endeavor, a fair and final solution will be well on its way.

B. R. KIRKLIN.



DANIEL BRAINARD
1812–1866

UNIV. OF ILLINOIS

MASTER SURGEONS OF AMERICA

DANIEL BRAINARD

THE first great surgeon of Chicago and the northwest was Daniel Brainard. Brainard was born in 1812 in the state of New York, where he received his early education. He graduated at Jefferson Medical College in 1834. He settled in Chicago in 1836 when it was a town of about 5,000 people. He had great confidence in the future of Chicago and the west and believed that they would become great and prosperous communities. He believed that such a future demanded the development of schools and colleges and professional schools, and as early as 1837 he secured a charter for a medical school which he named after Benjamin Rush, a signer of the Declaration of Independence and the father of American medicine. He went to Paris, which was then the center of medical education, in 1839 and remained until 1841 doing post-graduate work. He then returned to Chicago and organized Rush College which began to give medical courses in 1843.

Daniel Brainard began his medical career just before or at the very beginning of the period which is usually recognized as the period of modern medicine, the date of which is approximately 1850. In order to visualize this period let us recall the prominent medical figures of that time. Paris was generally regarded as the center of medical education. Here Claude Bernard (1813–1878) was teaching physiology and medicine. Cruveillier was teaching pathology and creating his great atlases of pathology. Armand Trousseau, one of the greatest clinical teachers, was giving his wonderful clinics in medicine. Larrey, Napoleon's great military surgeon, was still living. Brainard's teachers of surgery were the great French surgeons, Velpeau 1795–1867; Malgaigne 1806–1865; Nélaton 1807–1873. In England the great clinicians in medicine, Graves 1796–1853; Stokes 1804–1878; Bright 1789–1854; Addison 1793–1860, and Hodgkin were at work advancing medical knowledge and making medical history. In surgery, James Syme 1799–1870; William Ferguson 1808–1877; Sir Benjamin Brodie 1783–1862; Sir James Paget 1814–1899, were the leaders of British surgery of Brainard's time. In Germany Bernhard Von-Langenbeck 1810–1887 and Gustav Simon were the great teachers of surgery, and in Russia Pirogoff, the great military surgeon was the recognized leading surgical teacher and one of the most prominent figures in Russian medical history.

In America, Brainard's contemporaries included Marion Sims of South Carolina, 1813–1883; Samuel D. Gross of Philadelphia, 1805–1884; Henry Jacob Bigelow of Boston, 1816–1890. Brainard died in 1866. These contemporaries of Brainard's were more fortunate than he and lived to see the revolution in surgery brought about by Pasteur, Lister, and Koch. Brainard died in the cholera epidemic of 1866, just one year before Lister published his epoch making paper[1] on the "Antiseptic Principle in the Practice of Surgery."

Brainard made a second visit to Paris in 1852–1853; while there he read a paper before the Société de Chirurgie de Paris on the injection of iodine into the sac to cure spina bifida. At this time he was made a corresponding member of the Société de Chirurgie de Paris.

In 1854 he published in France a paper entitled "*Mémoire sur le traitement des fractures non-réunies et des difformités de os.*"

In 1854 at the meeting of the American Medical Association Brainard presented a paper on the same subject entitled, "An essay on a new method of treating ununited fractures and certain deformities of the osseous system." This was awarded the prize by the committee on prize essays for that year. This paper was a fine piece of surgical research. Brainard made an exhaustive study on dogs of the subject of ununited fractures and demonstrated that the then popular method of treating these cases with a seton placed between the ends of the bones was dangerous and ineffective and from his animal experiments and the study of clinical cases he devised the method of subcutaneously drilling in between the ends of the bones with a specially constructed bone drill for the purpose of producing in the old ununited fracture conditions closely resembling those of a recent fracture. He then placed the limb in splints as in a recent fracture. This work was thoroughly sound and scientific, and the results obtained were much better than those secured by any other method in the days before Lister. Brainard with his small drill which he was careful to have very bright and clean, made a single minute puncture in the skin over the fracture and then drilled in between the bones, the drill was then partially withdrawn, but not entirely, out of the small skin puncture and again in another direction the drill was passed between the ends of the bones. This was repeated three or four times and then the drill was withdrawn and the small puncture sealed with collodion and a splint was applied. Brainard succeeded in curing by this method, which he called a subcutaneous method, sixteen out of seventeen cases of ununited fracture and delayed union. In one case it failed, as did also the use of a seton and resection. This case was finally cured three years later by fixing the fragments together with iron wire. I have in a number of cases of ununited fracture and delayed union obtained good union by this use of the Brainard bone drill.

Brainard's injection of iodine into the sac of a spina bifida was a brilliant

[1] Lancet, London, 1867.

piece of original work which provided in a number of cases a cure for this serious condition for which there had been up to that time no relief. He used a solution of iodine five grains, iodide of potassium fifteen grains to an ounce of distilled water. He made a small puncture in the sound skin at the side of the tumor with a small sized trochar and evacuated part of the contents of the sac and then injected about the same amount of this iodine solution and applied a dressing retained with slight pressure. Until the full development of antiseptic and aseptic surgery made it possible to obtain primary wound healing in operative wounds, Brainard's iodine injection method offered these little patients with spina bifida the only cure available. Frazier in his excellent monograph on spinal surgery, refers to a report of a royal commission in England which discusses the value of the treatment of spina bifida by the Brainard iodine injections.

Another piece of original work by Brainard was what he called the extroduction of the bougie. He employed this method in cases of rupture of the urethra and in cases of extravasation of urine in old complicated stricture where the usual methods failed, and it was impossible to pass a catheter through the urethra into the bladder. He made a suprapubic drainage of the bladder and when at the end of several weeks the inflammation had subsided he passed a catheter from within the bladder outward to the external meatus. When this was not possible he divided the stricture by an external urethrotomy and with the catheter passed out from the bladder and an instrument inserted into the anterior urethra, the relations of the two parts were shown, thus making it possible to pass the catheter into the bladder.

Rush Medical College which Daniel Brainard founded has performed a very important function in the development of the west. Brainard's prophetic vision saw the great future of Chicago and the west, and saw the necessity of establishing a medical college which could educate medical men who could furnish good medical care for the enormous population which rapidly poured into the country. Brainard surrounded himself with a strong group of men, many of whom became important factors in the development of American medicine. Among the men in the early Rush faculty were such men as Austin Flint, Sr., who was later called to New York, Nathan S. Davis, the founder of the American Medical Association, and William H. Byford, one of the pioneers in American gynecology and obstetrics.

Brainard founded a great surgical clinic on the very sound surgical knowledge which he had acquired from his European training. His conception was that the basis of surgery must be built on a knowledge of anatomy, physiology, and pathology and that the three important functions of teaching, clinical work, and research must all be carried on to develop a successful surgical clinic. This conception of Brainard's has been transmitted to his successors—Moses Gunn,

Charles T. Parkes, Nicholas Senn, John B. Murphy, and others—and Brainard's old clinic has continued to grow stronger and stronger with the passing years and with the great development that has taken place in anatomy, physiology, and pathology which still continue to form the foundation on which the clinic is built.

Daniel Brainard founded a surgical clinic that has become an important factor in American surgery. One of its functions which has become a tradition in the clinic is the training of younger men to become teachers of surgery. In this it has been successful as shown by the fact that a number of the most important surgical chairs in this country are now filled with men trained in the clinic which Brainard founded.

We can obtain a good idea of the estimate of Brainard's work by the men who shortly succeeded him from an address delivered by Nicholas Senn when he assumed the professorship of surgery founded by Brainard. He said, "Brainard, the founder of this institution and the first occupant of the chair of surgery, was a great surgeon, a gifted teacher and an original investigator. His giant intellect was not content in acquiring, practising, and teaching what was known at his time, but sought new fields for exploration, and the knowledge thus gained was freely infused into his students. Brainard's work in the field of experimental surgery brought him an international fame. His work left numerous permanent impressions on surgical literature; it created a stimulus which took possession of students and progressive surgeons throughout the world, leading them into new and unexplored territories."

ARTHUR DEAN BEVAN.

THE SURGEON'S LIBRARY

REVIEWS OF NEW BOOKS

THE book on *Orthopædic Surgery*,[1] by Walter Mercer, is an elaboration of lectures and clinics on orthopedic subjects conducted by the author at the University of Edinburgh, the Edinburgh Royal Infirmary, and other hospitals. The writer is associated with Professor John Fraser, who has written the foreword. There are eighteen well arranged chapters covering about seven hundred pages.

The introductory chapter covers the history, definition, and scope of orthopedic surgery and briefly discusses the routine examination in an orthopedic case and the technique of plaster-of-paris work. A concise chapter on congenital deformities follows. The next chapter on general affections of the skeleton includes nutritional and glandular disturbances. Referring to generalized osteitis fibrosa cystica, the author discusses briefly the recent work on associated lesions of the parathyroid glands. Quoting Turnbull he states that the nature of the parathyroid enlargement is never neoplastic, but that histologically the gland presents the picture of functional overactivity. The author describes Fraser's classification of primary bone tumors, dividing them into simple, border line, malignant, and tumors of unknown origin. Metastatic tumors and inflammatory conditions are omitted.

A chapter is devoted to tuberculosis of bones, another to tuberculosis of joints and another to non-tuberculous infections of joints due to specific infections such as pyogenic, pneumococcal, and gonococcal arthritis and Charcot's disease.

Chronic arthritis is described under two main types without adding further confusion to the numerous and frequently confusing classifications presented in recent literature.

Chapters on epiphyses, affections of the spine, shoulder, knee, and foot contain comprehensive descriptions. The chapters on complications of trauma and affections of soft tissues emphasize the advantage of the general surgical training of the author.

The bibliography is copious and explicit, being arranged according to chapters and affections described.

The book is concisely and systematically written, and generally well illustrated, although some of the roentgenograms could have been better chosen. The line drawings (done by the author's wife) accomplish the purpose for which they are intended, although done by one who evidently does this work as an avocation. Future editions may refer to Morrison's bipp treatment of osteomyelitis, the work of Crowe, Hadjapoulos, Burbank, and others in the vaccine treatment of arthritis, and Galeazzi in the treatment of scoliosis. In discussing recurrent dislocation of the shoulder, Nicola's operation should be included. However, one cannot expect everything to be included in such a concise volume. The merits of this book warrant its addition to the libraries of students, practitioners, and orthopedic surgeons.

DANIEL H. LEVINTHAL.

IN this interesting volume on surgery of the stomach and duodenum,[2] Rhéaume endeavors to present the operative procedures as practiced in North America in connection with the diseases of these organs. The first four chapters are devoted to the evolution of gastric surgery, anæsthesia, topographic anatomy, and the pre-operative treatment. The remaining twelve chapters describe in detail typical procedures upon the stomach and duodenum.

The contributions of the American surgeons are given a prominent place. The operative procedures are illustrated with drawings frequently borrowed from well known sources, such as the Mayos, Balfour, Coffey, and others. Each chapter is supplemented with a small but well chosen bibliographic index in which the names of American surgeons predominate. The entire subject matter is admirably presented and will, no doubt, stimulate much interest among the continental French surgeons.

GEORGE HALPERIN.

THE first edition of this work[3] (1911) by the present professor of anatomy at McGill University was prepared from lectures given to candidates for the Oxford diploma of ophthalmology. The lectures were illustrated with dissections and numerous photographs of these add greatly to the value of the book, which is the only extensive treatment of the subject in English. The 1932 edition contains 19 additional illustrations, chiefly of dissections and 30 pages of additional text. No chapters have been added, the additions being made necessary by 190 contributions to the literature during the past 10 years which required consideration in the book.

[1] ORTHOPÆDIC SURGERY. By Walter Mercer, M.B., Ch.B., F.R.C.S. (Edin.), F.R.S. (Edin.). With a foreword by John Fraser, M.C., M.D., Ch.M., F.R.C.S.E. London: Edward Arnold & Co., 1932.

[2] TECHNIQUE CHIRURGICALE ESTOMAC ET DUODÉNUM. By Pierre Rhéaume. Paris: Masson et Cie, 1932.

[3] THE ANATOMY OF THE HUMAN ORBIT AND ACCESSORY ORGANS OF VISION. By S. Ernest Whitnall, M.A., M.D., B.Ch. (Oxon.), M.R.C.S. L.R.C.P. (Lond.). 2d ed. New York and London: Oxford University Press, 1932.

About one-fourth of the book is devoted to the bony orbit and its relation to the accessory sinuses, a third to the eyebows, lids, conjunctiva and lacrymal apparatus and the remainder to the globe, extra-ocular muscles, nerves and cerebral pathways. Not only is the normal anatomy of the parts considered, but their development, common anomalies, and the normal changes which occur during life. We are reminded, for instance, that the roof of the orbit varies from 1 to 4 millimeters in thickness, and that "it is often of such paper-like delicacy that a tap with the finger nail will break through it and dehiscences due to atrophy of the bone in old age may be present, the peri-orbita then lying in contact with the dura." Similar dehiscences may occur in the floor of the orbit, "whereby the contents are only separated from the lining of the maxillary sinus by the peri-orbita." The variations in the sinuses, which are of especial importance in the relations of the lacrymal sac, are well discussed.

The question of the involuntary orbital muscles of the orbit and their possible importance in the mechanism of exophthalmos is fully treated. This point, surprisingly enough, has never been settled for ophthalmologists. In the region of the inferior orbital fissure is a mass of smooth muscle fibers fused with the peri-orbita. This is the "orbital muscle of Mueller," innervated by the sympathetic, which has been thought to protrude the eye by becoming thicker during contraction. The author points out that while in animals it may be of importance, in man it is purely vestigial and excitation of its sympathetic innervation does not cause protrusion of the globe. It is too small, he concludes, to cause protrusion of the globe by pressure on the orbital contents and the veins which pass through it are too small to produce the same effect by their occlusion. The other muscle which has been considered of importance in exophthalmos and which is often referred to as the protrusor bulbi, is the peri-bulbar muscle or musculus capsulo-palpebralis of Landström. Landström's muscle, it may be noted, is erroneously figured in Bing's *Gehirn und Auge* as being at the apex of the orbit, evidently by confusion with the orbital muscle previously described. (Reviewer's note) Landström's muscle itself extends as a membrane around the anterior half of the globe, being continuous anteriorly with the involuntary muscles of the lid. Since it lies mainly in front of the globe, the author evidently does not believe that its contraction could cause exophthalmos, although it could, as Adler apparently proved, raise the intra-ocular tension by compressing the globe. He believes the most probable cause of the exophthalmos in Graves' disease is dilatation of the orbital blood vessels by excitation of the sympathetic nervous system. He has dissected two orbits of patients dying of Graves' disease without finding anything abnormal.

In the section on the cerebral pathways, modern work, especially that of Bromver on the visual pathway and the retinal representation in the occipital cortex, receives careful discussion.

The format of the book and its illustrations are up to the best standards and the work forms a fitting companion to J. Parsons Schaeffer's work on the nose and paranasal sinuses in the library of anyone practicing surgery of the head, as well as of the ophthalmologist. SANFORD R. GIFFORD.

BOOKS RECEIVED

Books received are acknowledged in this department, and such acknowledgment must be regarded as a sufficient return for the courtesy of the sender. Selections will be made for review in the interests of our readers and as space permits.

OXFORD MEDICAL PUBLICATIONS. The Early Diagnosis of the Acute Abdomen. By Zachary Cope, B.A., M.D., M.S. (Lond.), F.R.C.S. (Eng.). 6th ed. New York and London: Oxford University Press, 1932.

OUTLINE OF PREVENTIVE MEDICINE; FOR MEDICAL PRACTITIONERS AND STUDENTS. Prepared Under the Auspices of The Committee on Public Health Relations New York Academy of Medicine. 24 Contributors. Editorial Committee, Frederic E. Sondern, Chas. Gordon Heyd, E. H. L. Corwin. 2d rev. and enl. ed. New York: Paul B. Hoeber, Inc., 1932.

PRACTICAL OBSTETRICS FOR STUDENTS AND PRACTITIONERS. By P. Brooke Bland, M.D. Assisted by Thaddeus L. Montgomery, M.D. Philadelphia: F. A. Davis Company, 1932.

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THE ART OF ANÆSTHESIA. By Paluel J. Flagg. 5th ed, rev. Philadelphia and London: J. B. Lippincott Company. 1932.

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NON-TROPICAL SPRUE; A STUDY IN IDIOPATHIC STEATORRHŒA. By Th. E. Hess Thaysen, M.D. Copenhagen: Levin & Munksgaard, 1932; London: Oxford University Press, 1932.

GEGENWARTSFRAGEN DER FRAUENKUNDE; VORLESUNGEN GEHALTEN AN DER BERLINER FRIEDRICH-WILHELM-UNIVERSITAET. By Dr. W. Liepmann. In collaboration with Dr. Paul Gornick. Leipzig: S. Hirzel, 1933.